US010117647B2

(12) **United States Patent**
Cheney

(10) **Patent No.: US 10,117,647 B2**
(45) **Date of Patent: Nov. 6, 2018**

(54) **ELASTIC ORTHOPEDIC IMPLANT AND METHOD OF MANUFACTURING THEREOF**

(71) Applicant: **BioMedical Enterprises, Inc.**, San Antonio, TX (US)

(72) Inventor: **Daniel F. Cheney**, San Antonio, TX (US)

(73) Assignee: **BioMedical Enterprises, Inc**, San Antonio, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 260 days.

(21) Appl. No.: **15/254,578**

(22) Filed: **Sep. 1, 2016**

(65) **Prior Publication Data**

US 2017/0065275 A1 Mar. 9, 2017

Related U.S. Application Data

(60) Provisional application No. 62/213,774, filed on Sep. 3, 2015.

(51) **Int. Cl.**
A61B 17/064 (2006.01)
A61B 17/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 17/064*** (2013.01); ***A61B 17/0642*** (2013.01); *A61B 2017/00526* (2013.01); *A61B 2017/00867* (2013.01); *A61B 2017/0641* (2013.01); *A61B 2017/0645* (2013.01)

(58) **Field of Classification Search**
CPC A61B 17/0642; A61B 2017/0641; A61B 17/064
See application file for complete search history.

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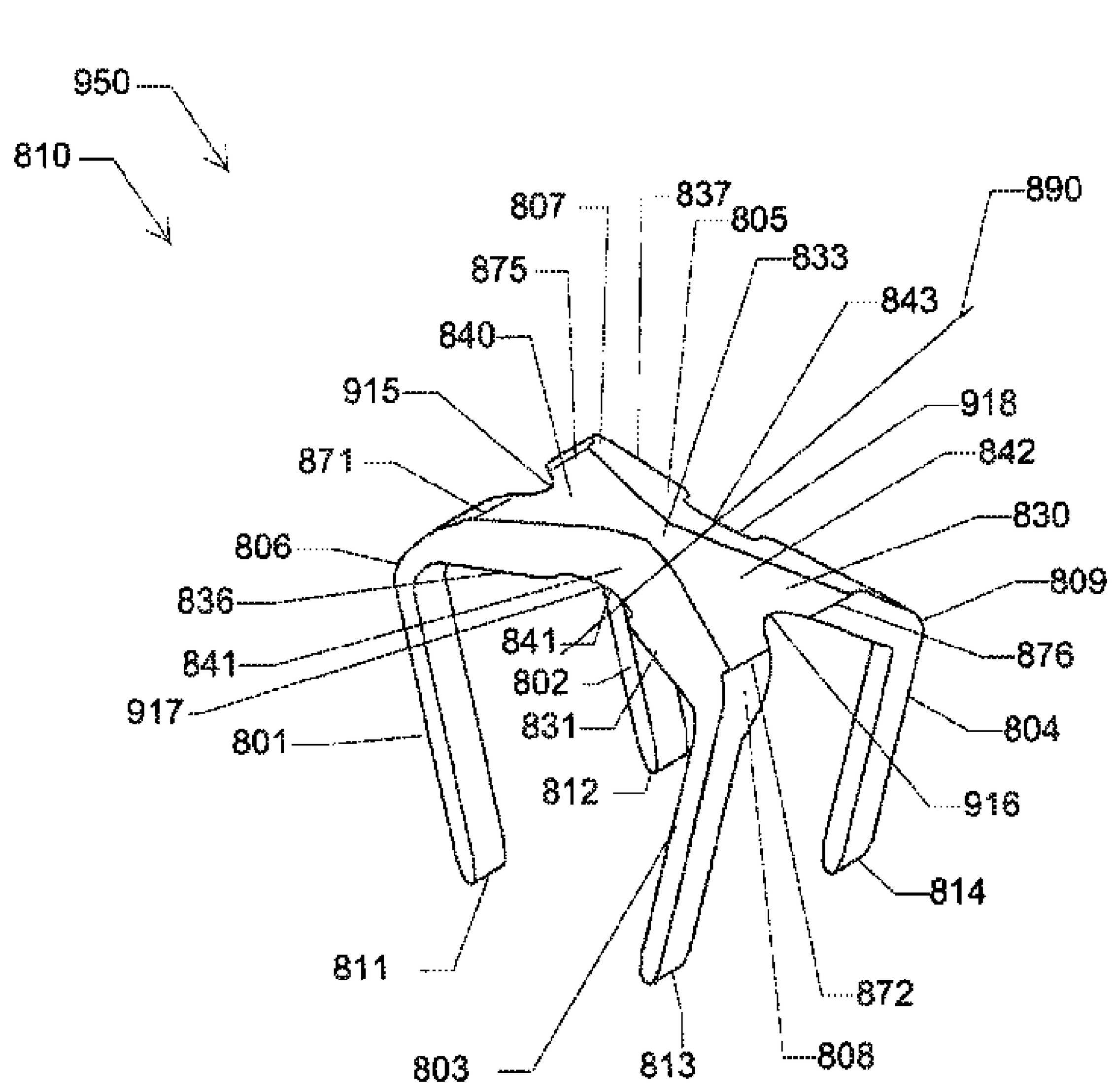
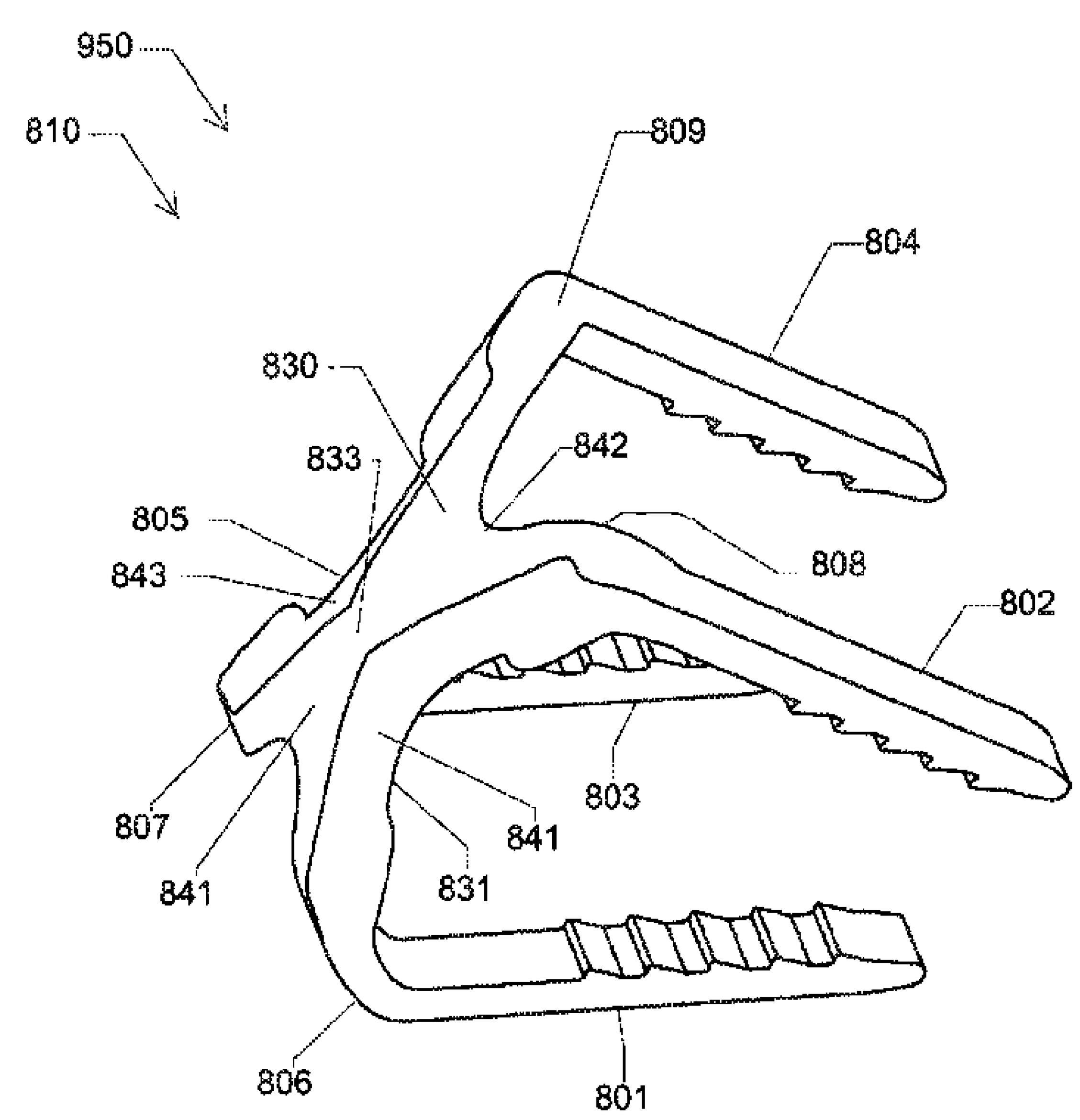
Primary Examiner — Christian Sevilla
(74) *Attorney, Agent, or Firm* — Christopher L. Makay

(57) **ABSTRACT**

An orthopedic implant includes a bridge and at least a first leg extending from a first end of the bridge and a second lee extending from the second end of the bridge. The bridge includes a first upper section and a second lower section. The first upper section includes surfaces that are non-orthogonal and taper from a central surface to provide the first upper section with a non-uniform cross-section. The second lower section includes surfaces that are non-orthogonal and taper from a central surface to provide the second lower section with a non-uniform cross-section. The non-uniform cross-sections of the first upper section and the second lower section flatten the profile of the bridge, thereby producing an orthopedic implant with a smooth composite surface.

28 Claims, 25 Drawing Sheets





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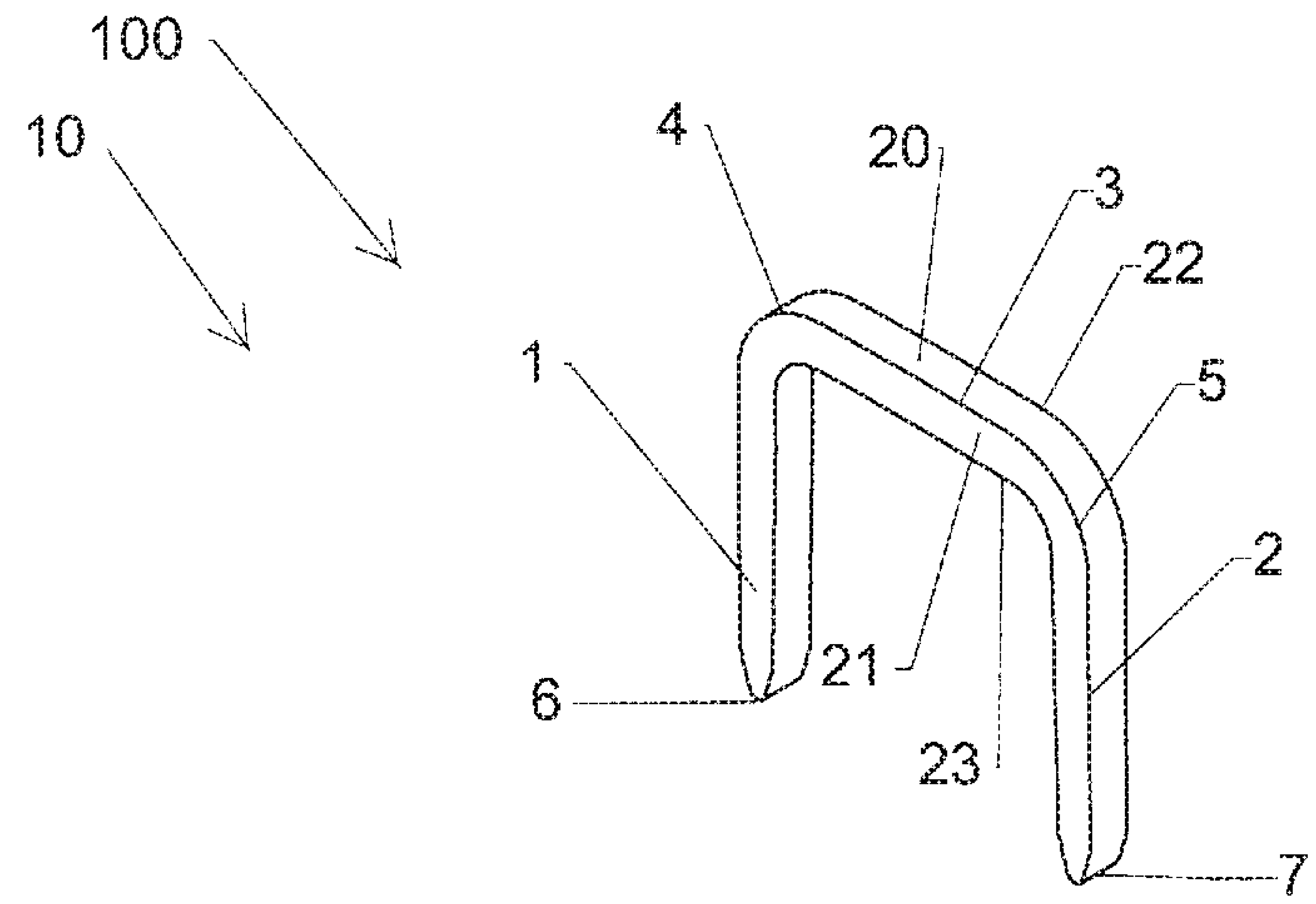

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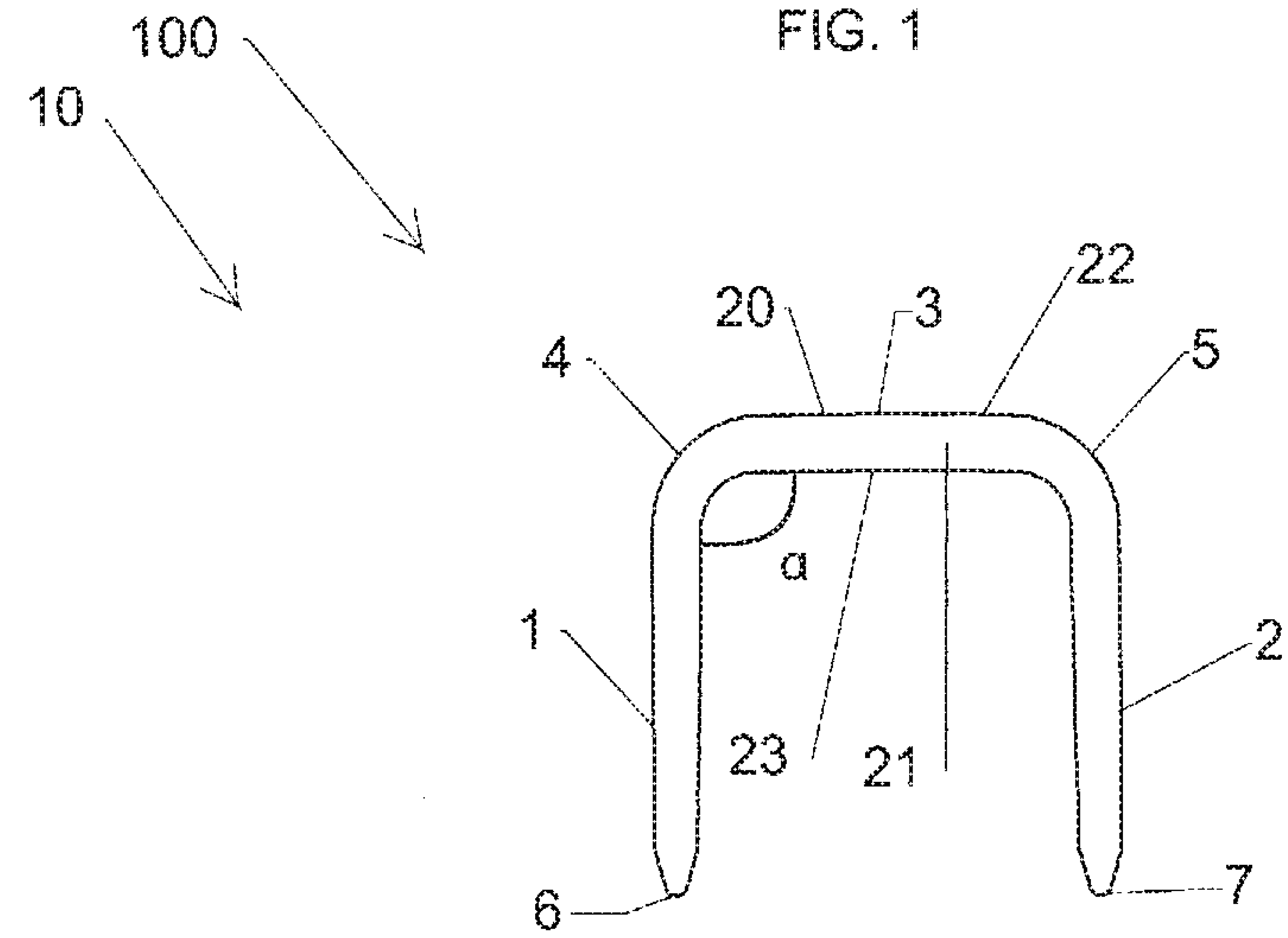

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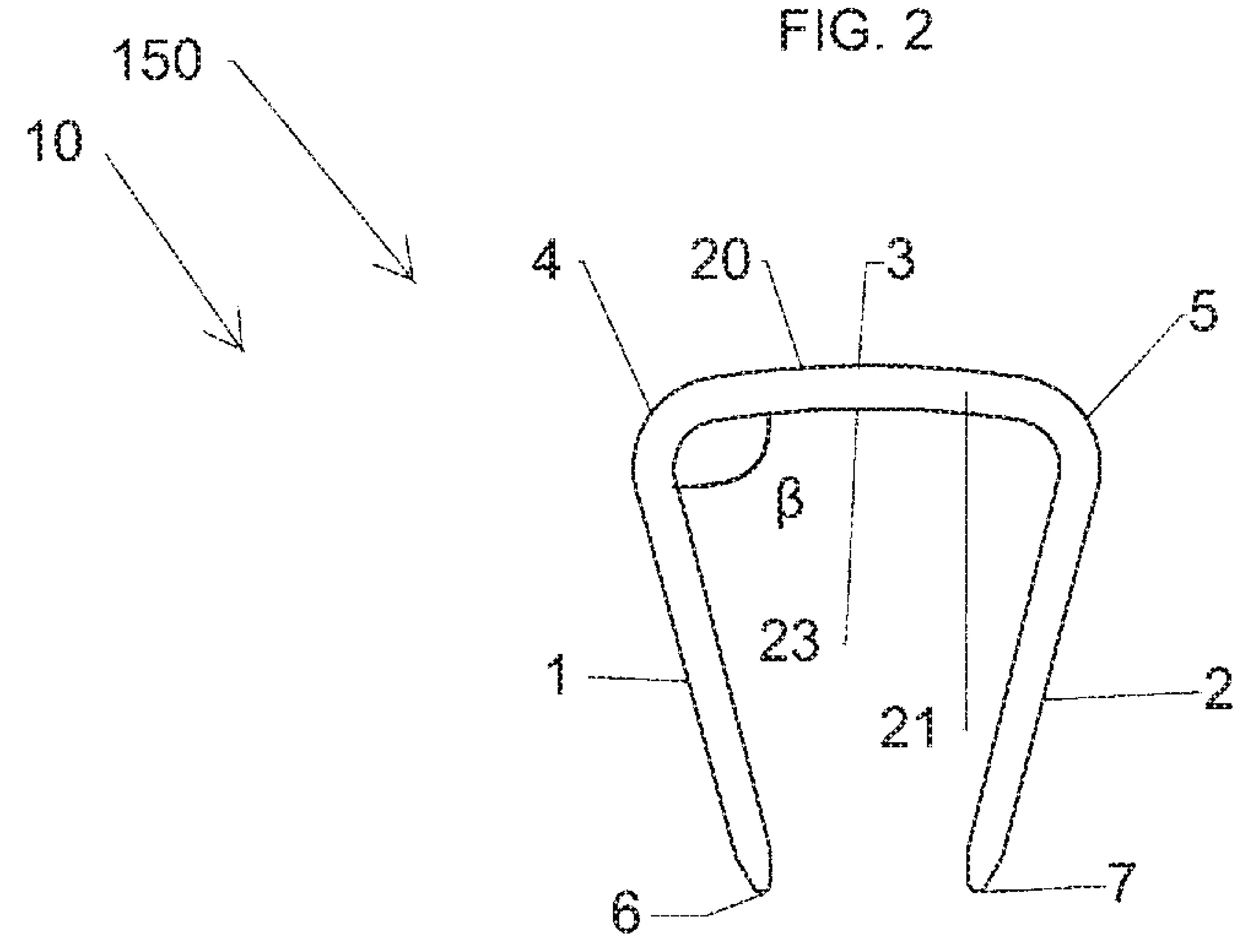

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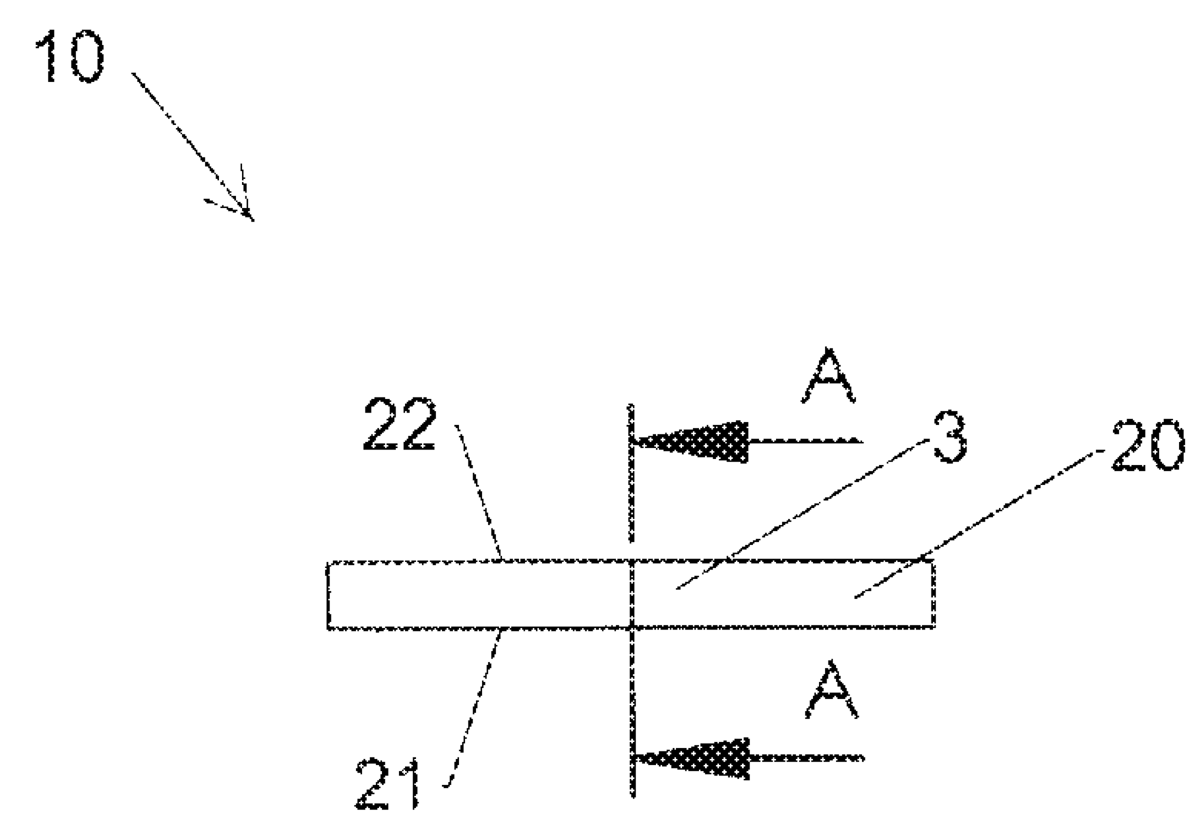

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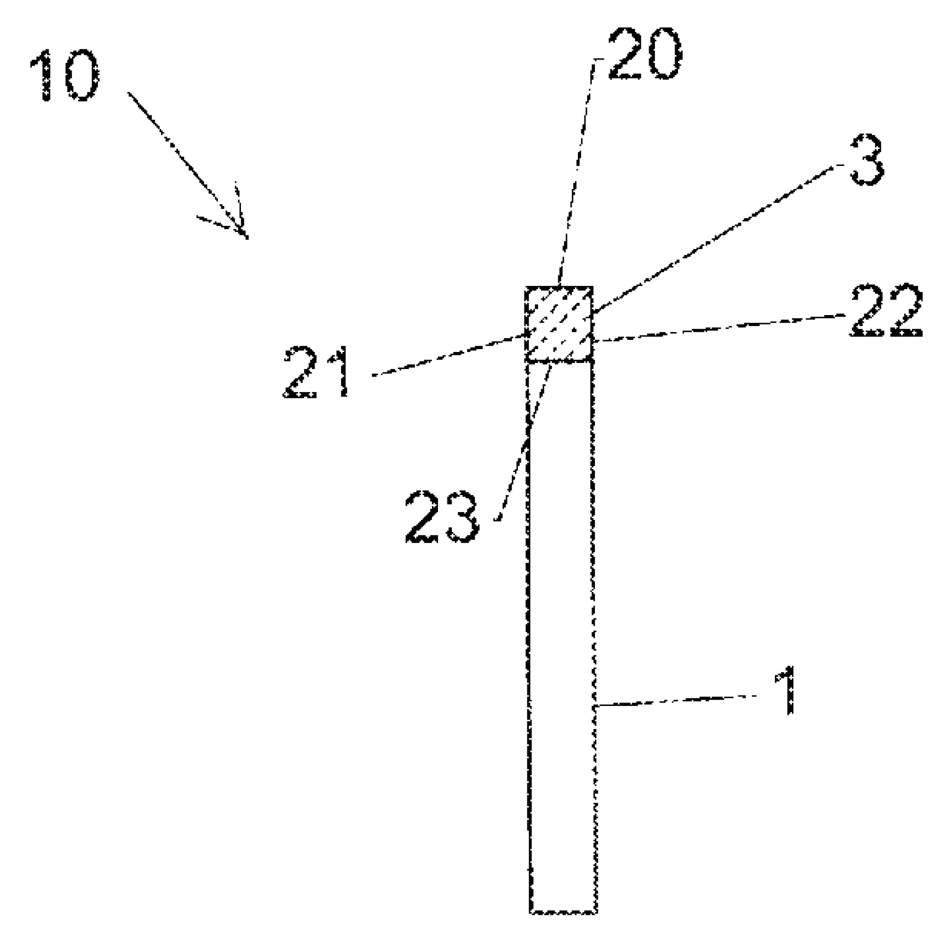

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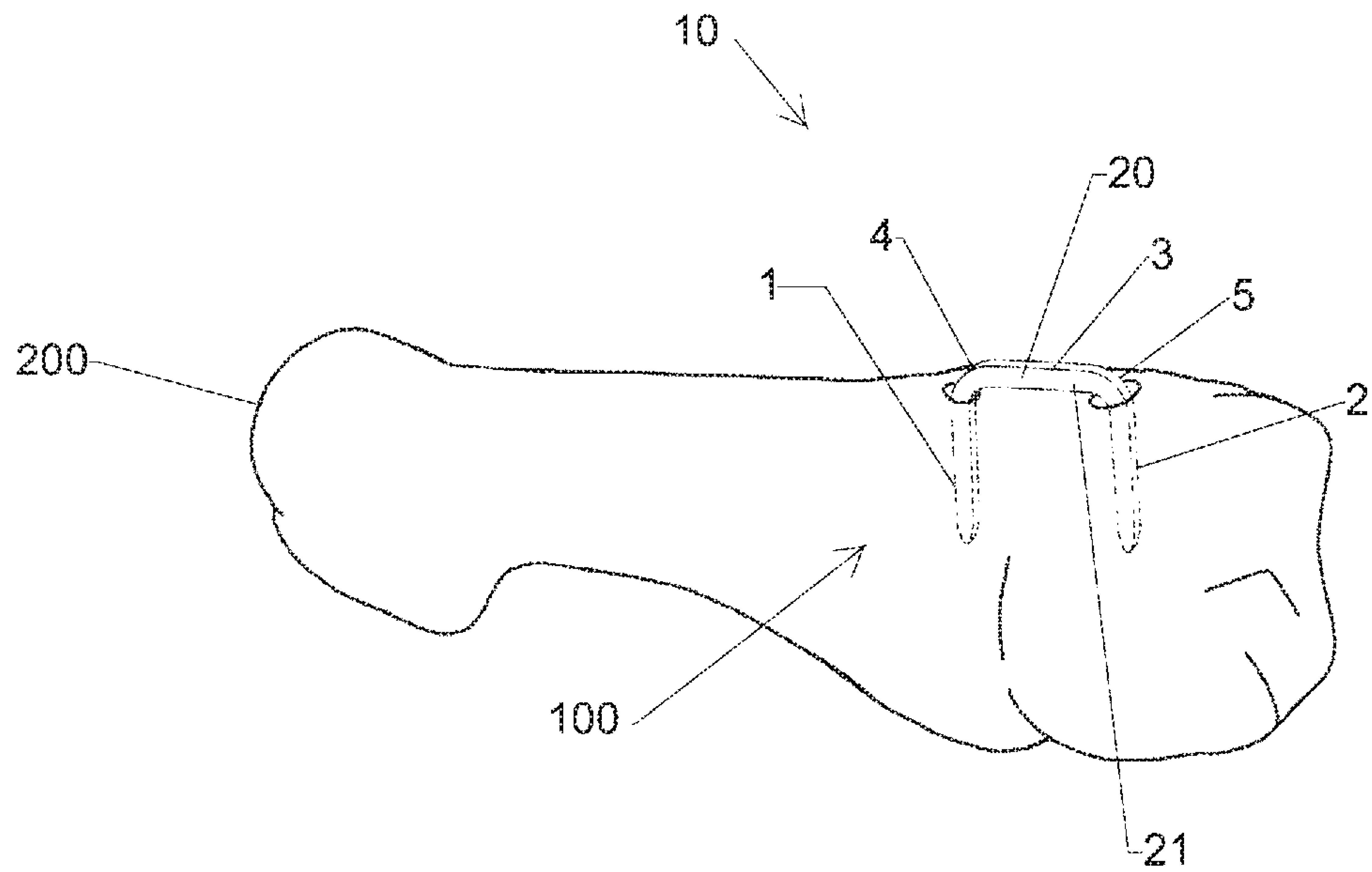

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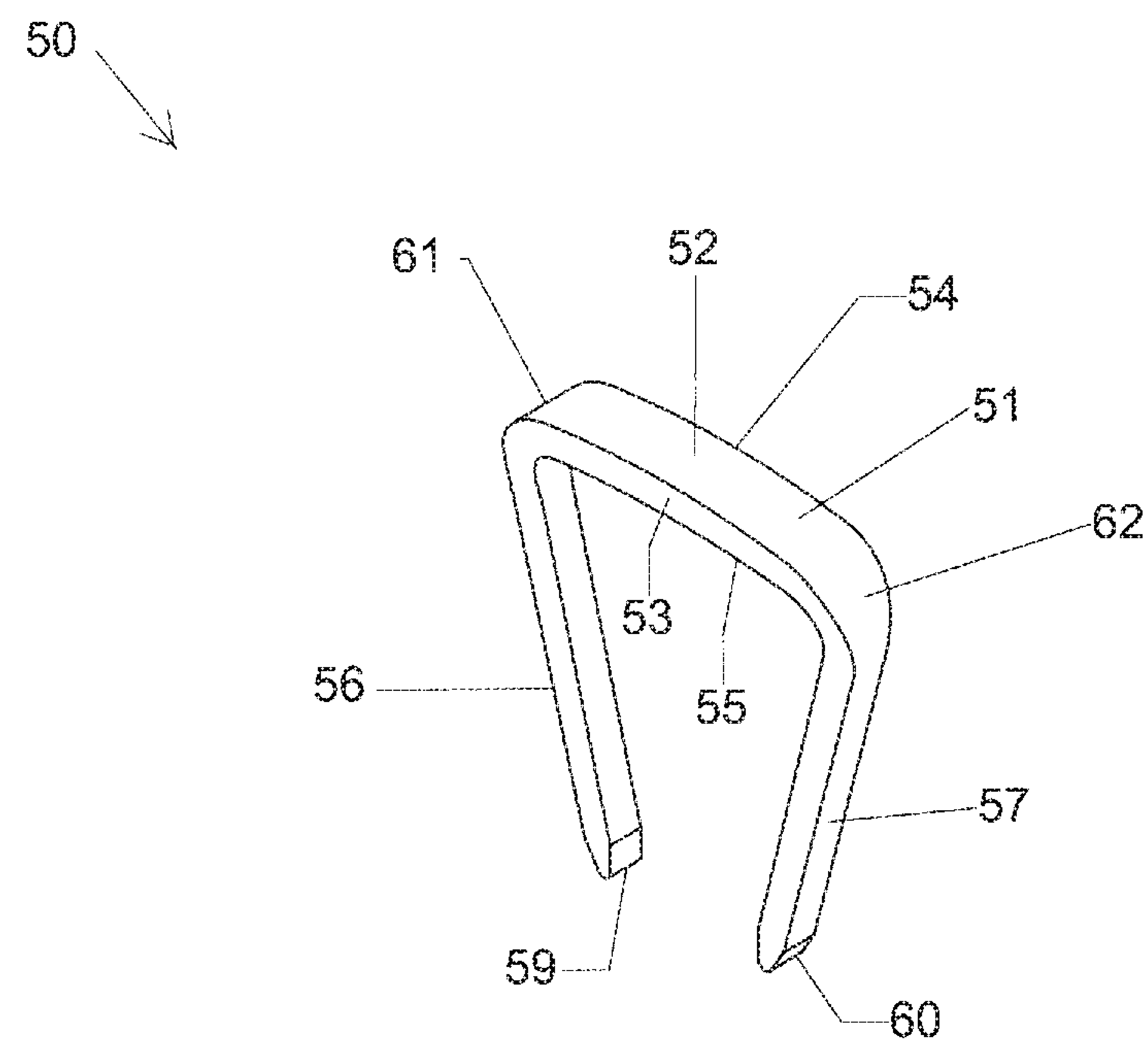

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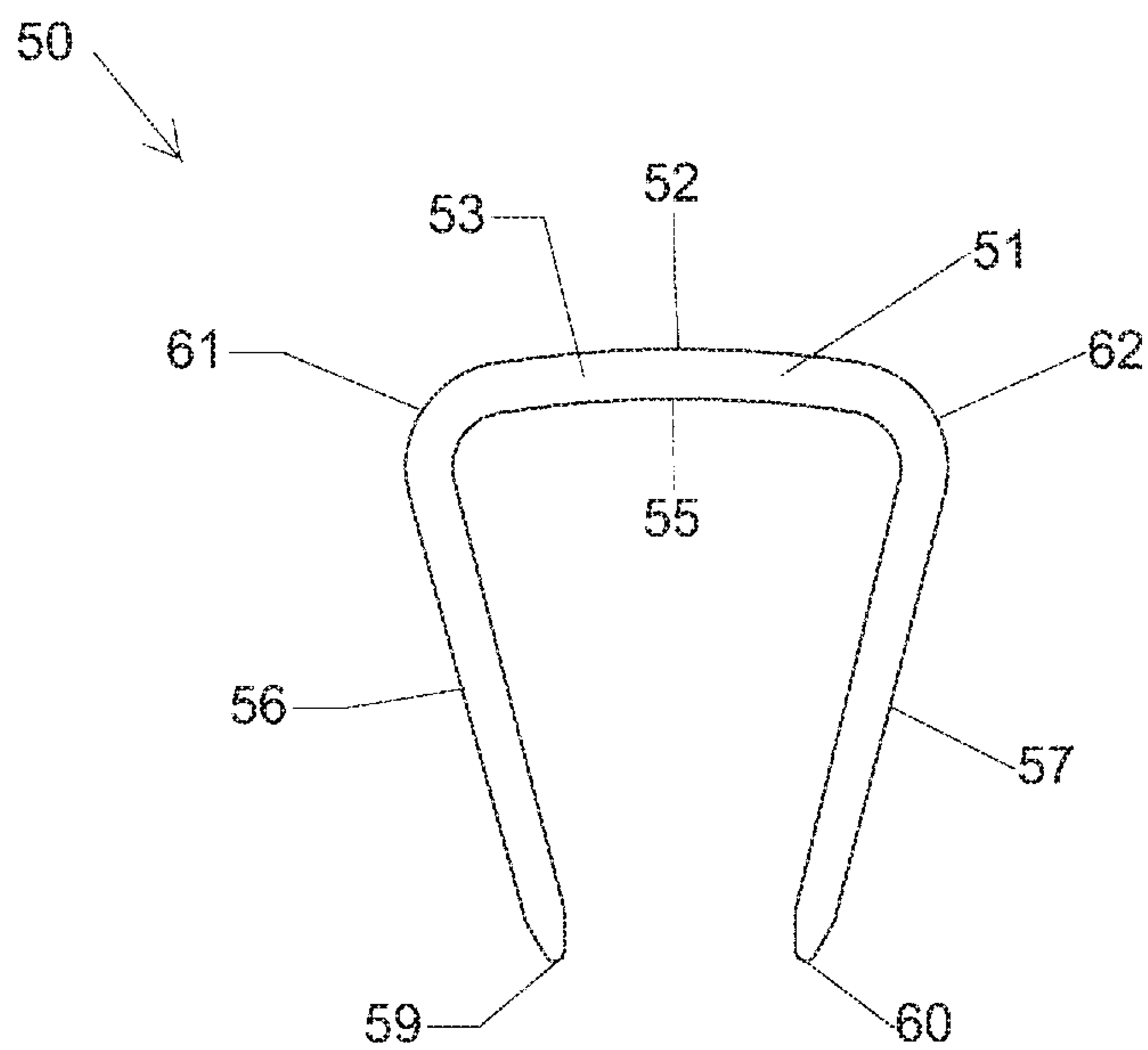

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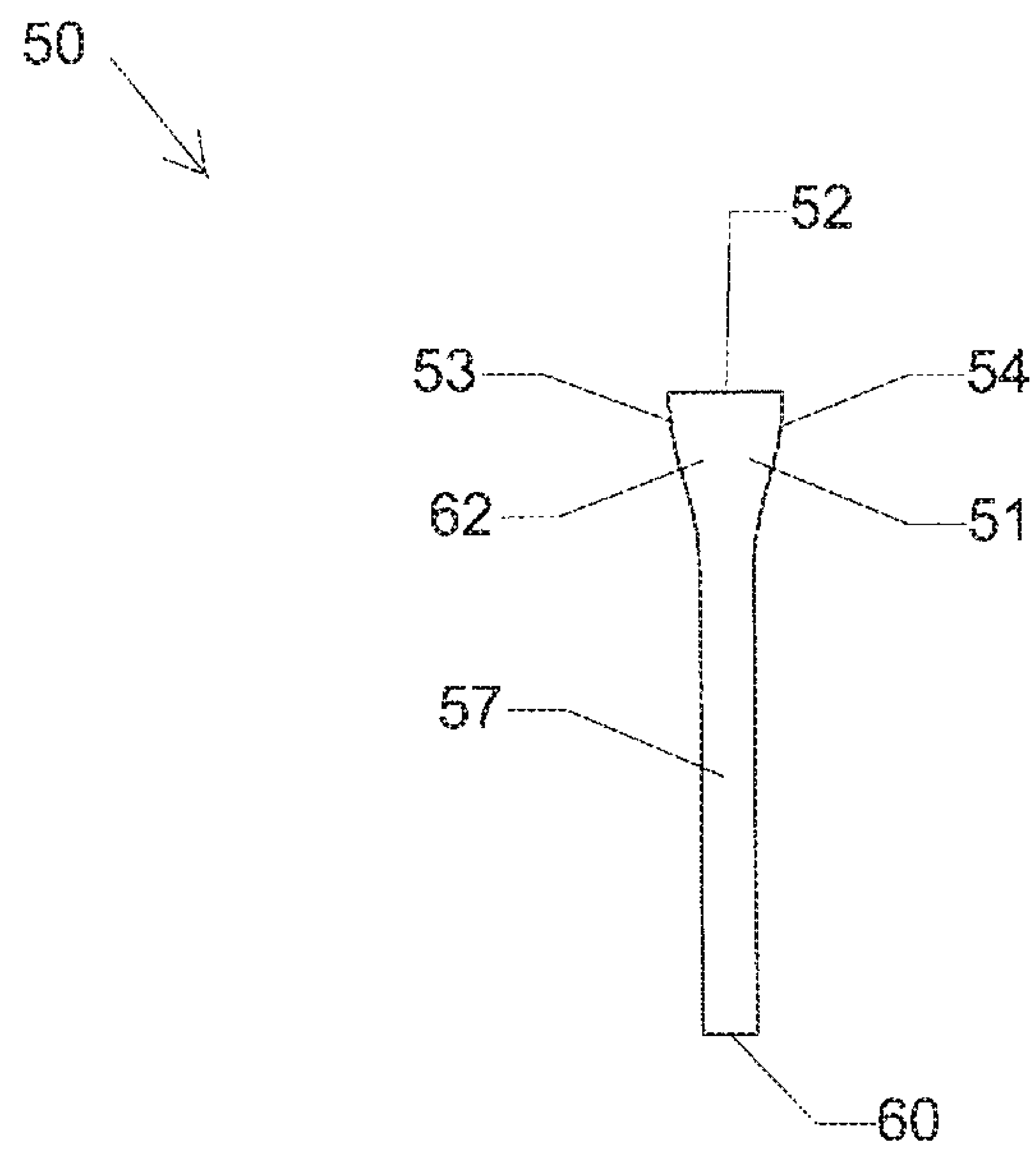

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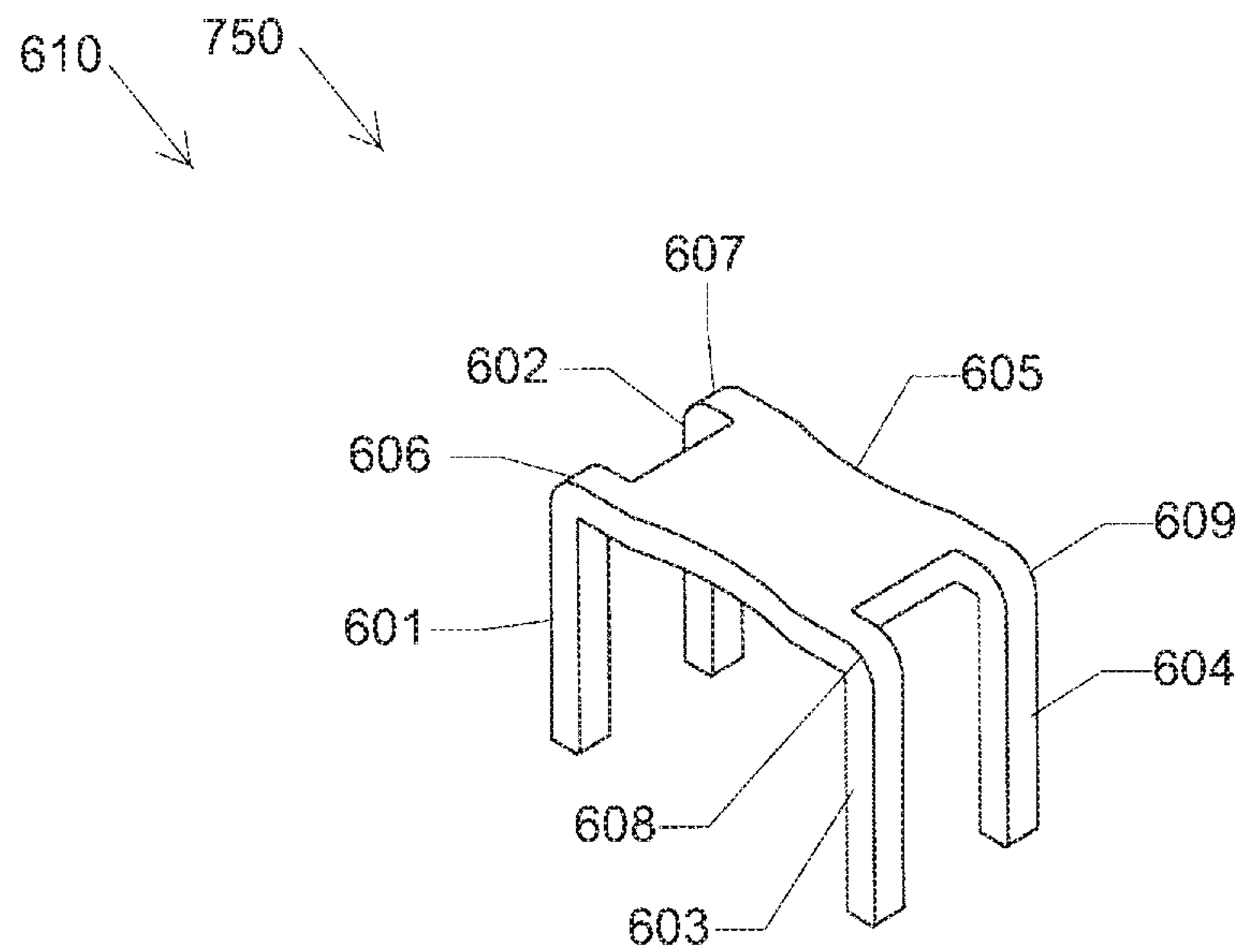

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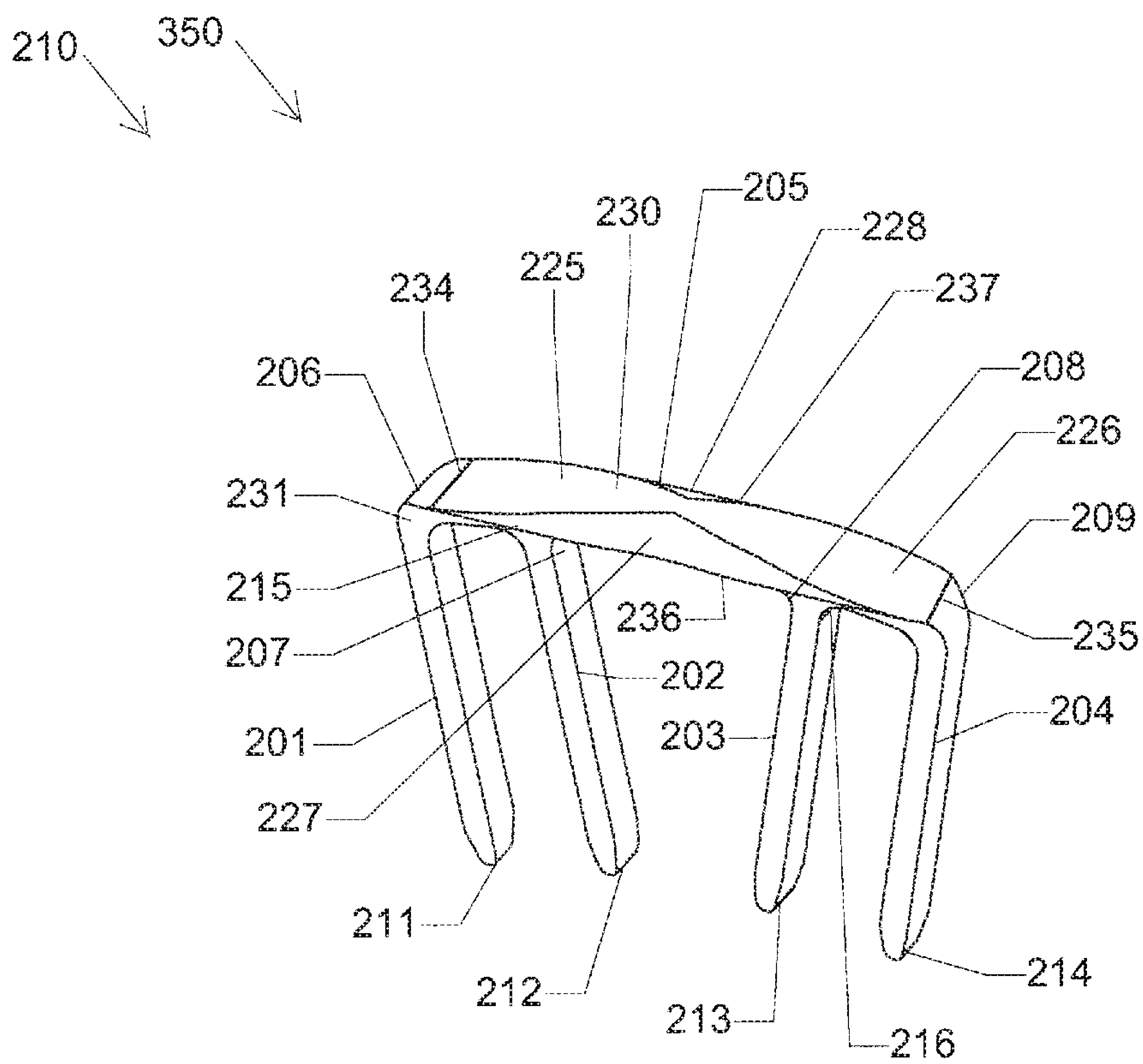

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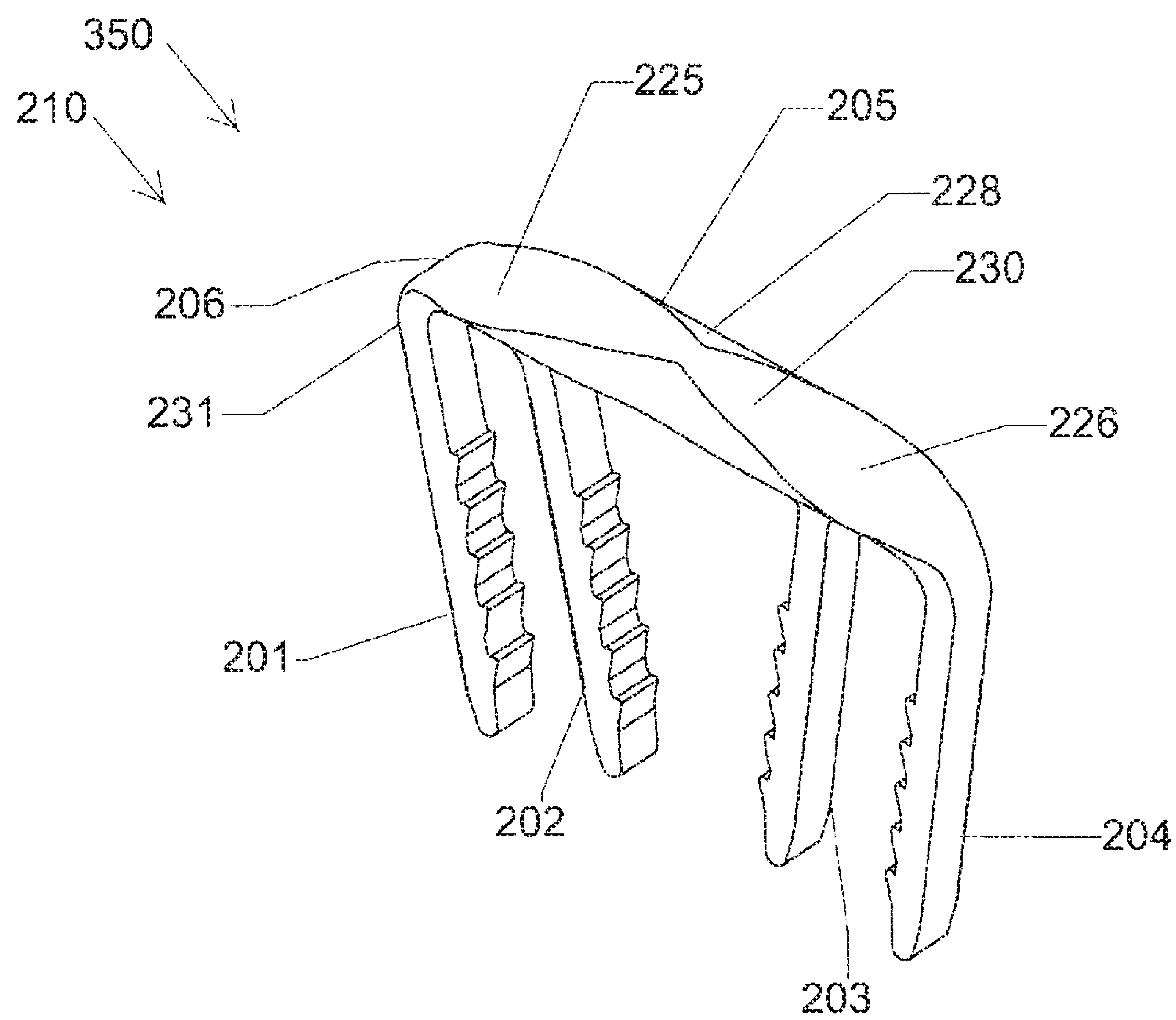
FIG. 11



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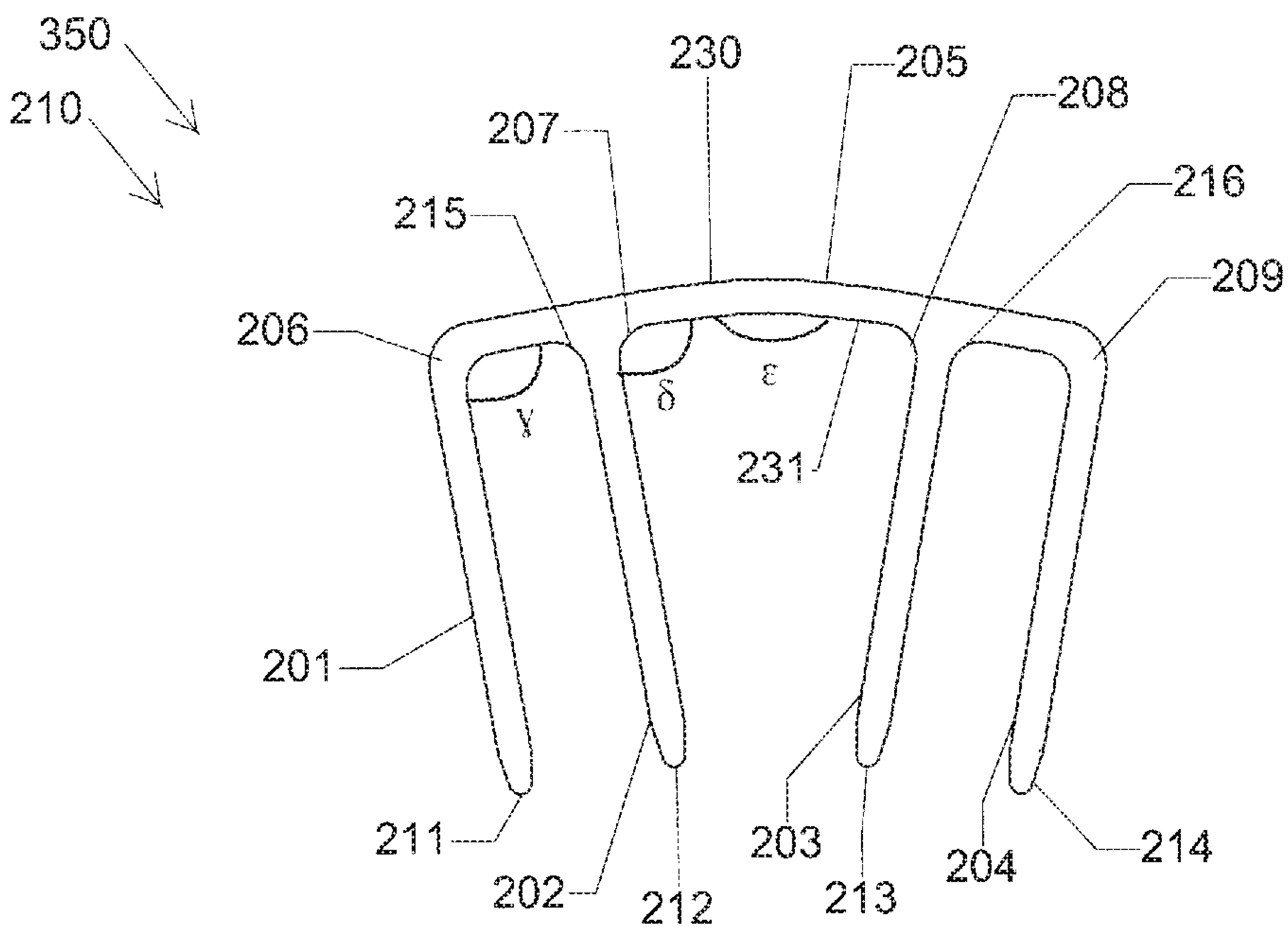
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FIG. 13

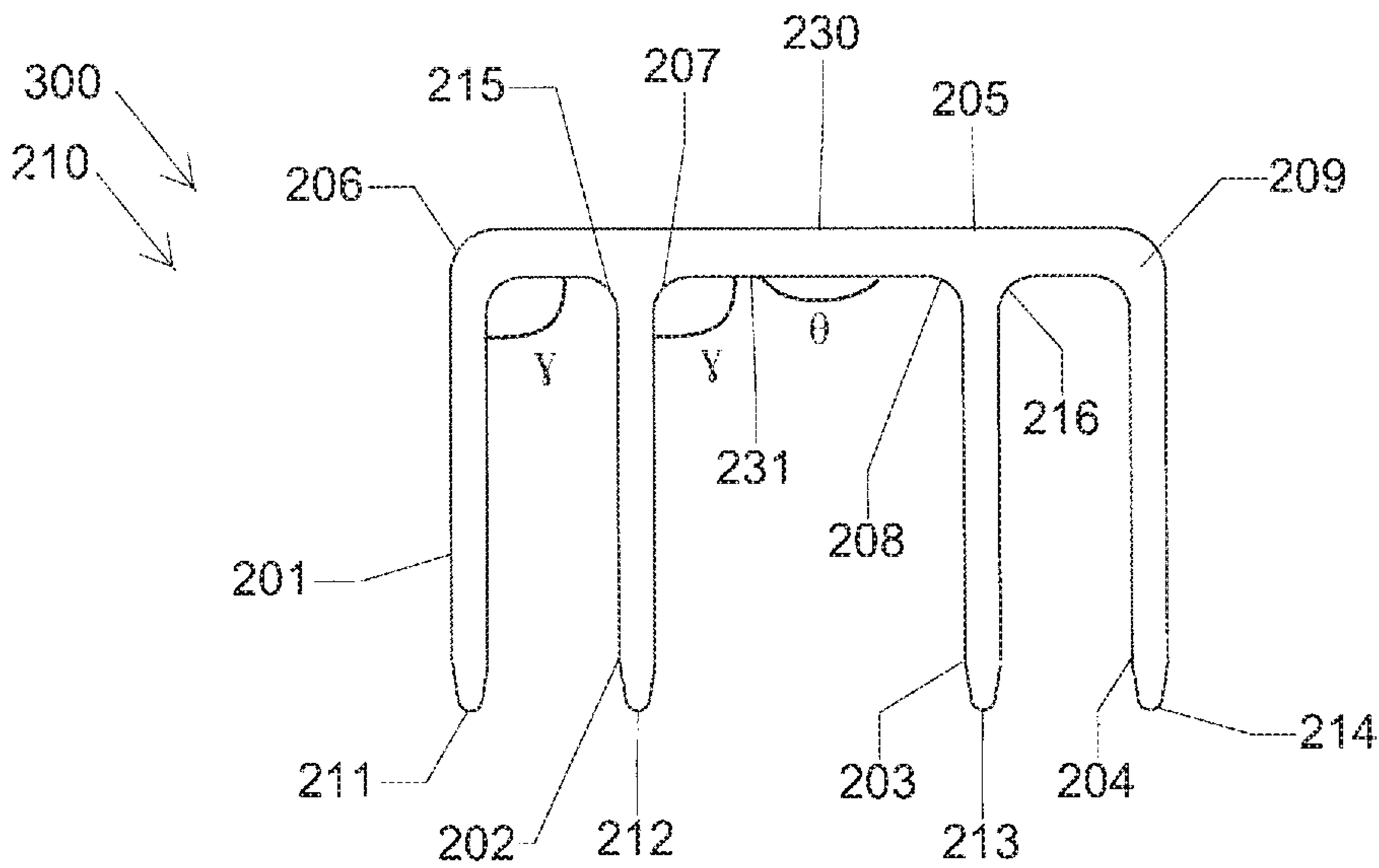
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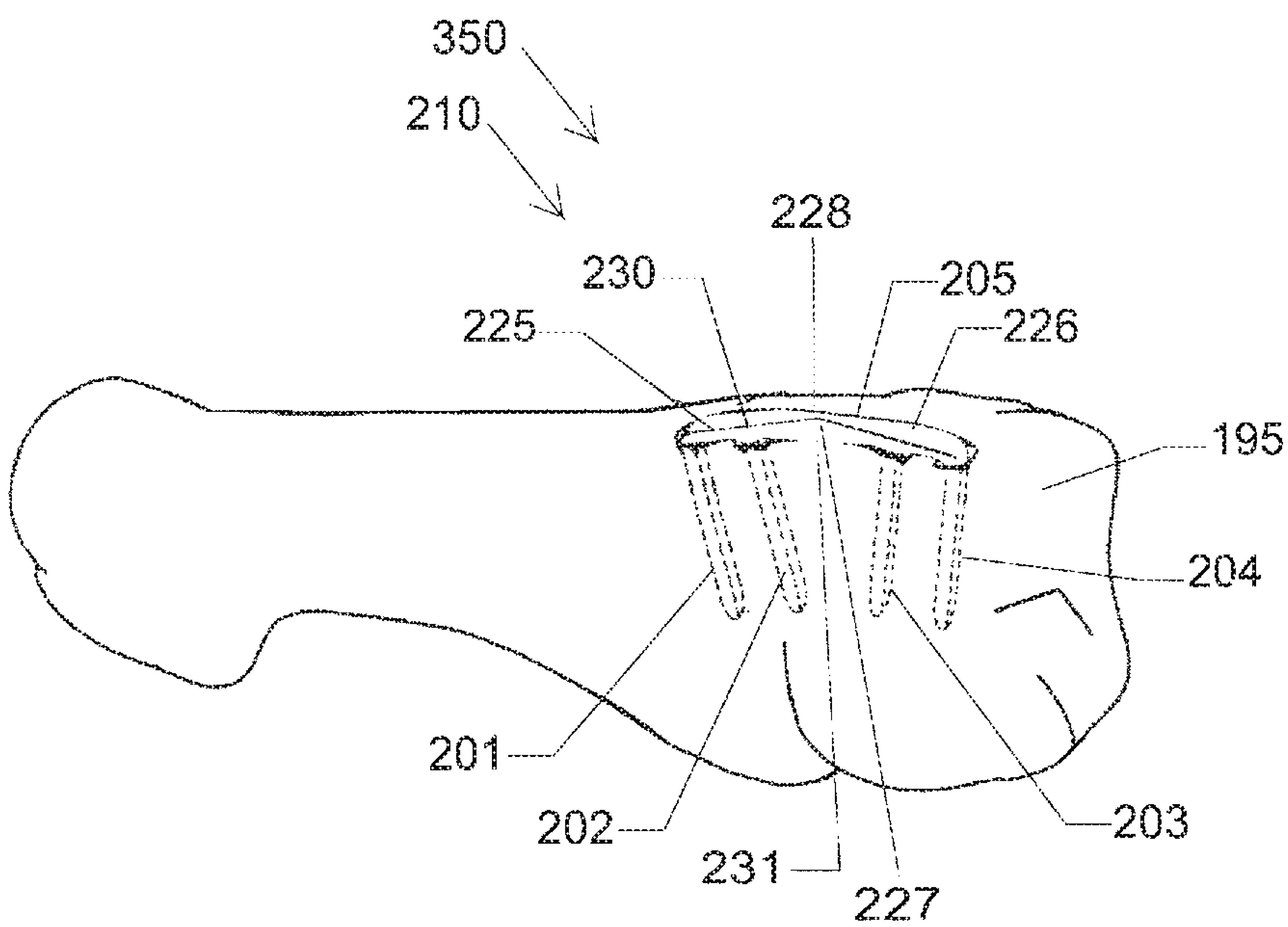
FIG. 14



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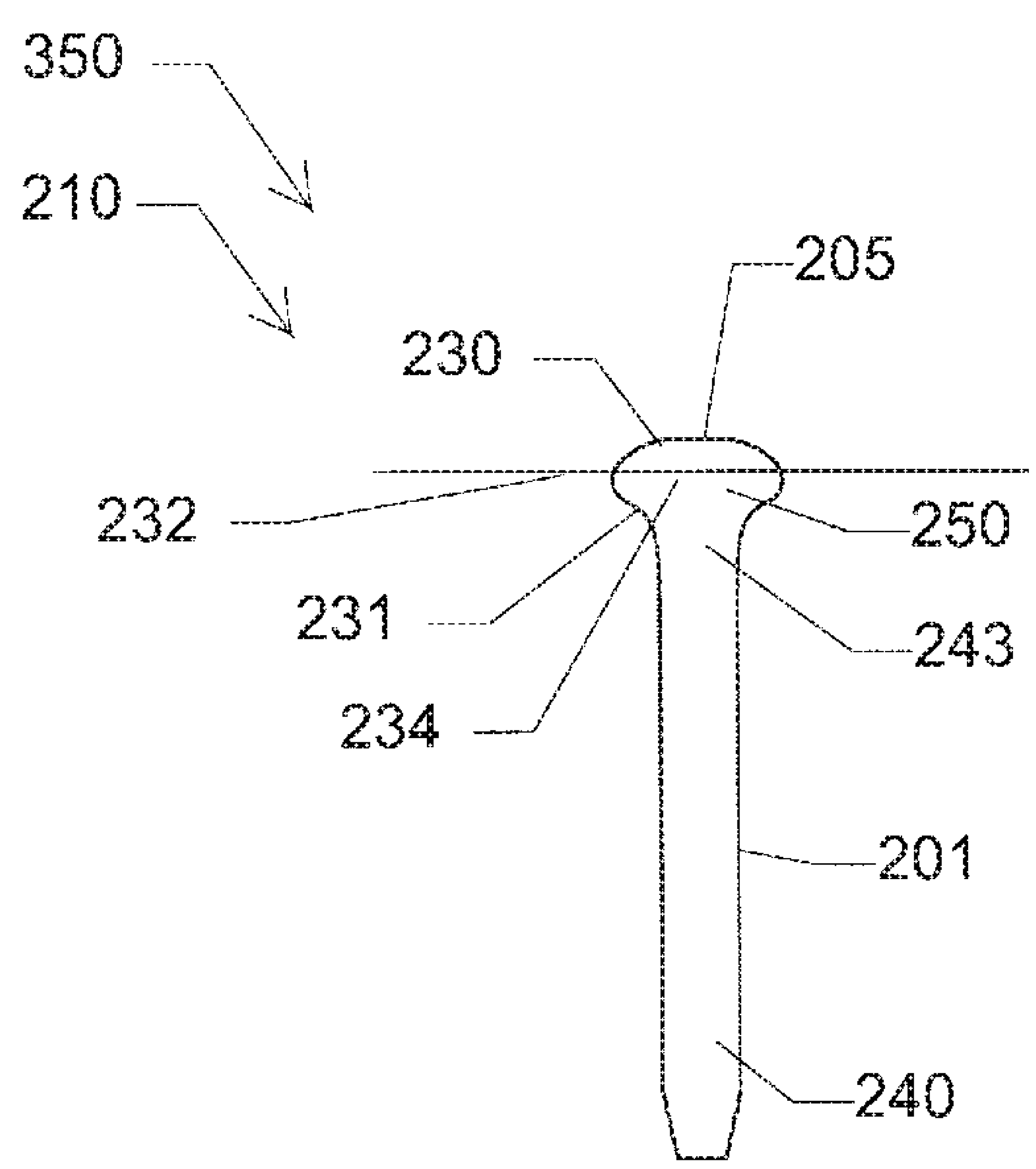

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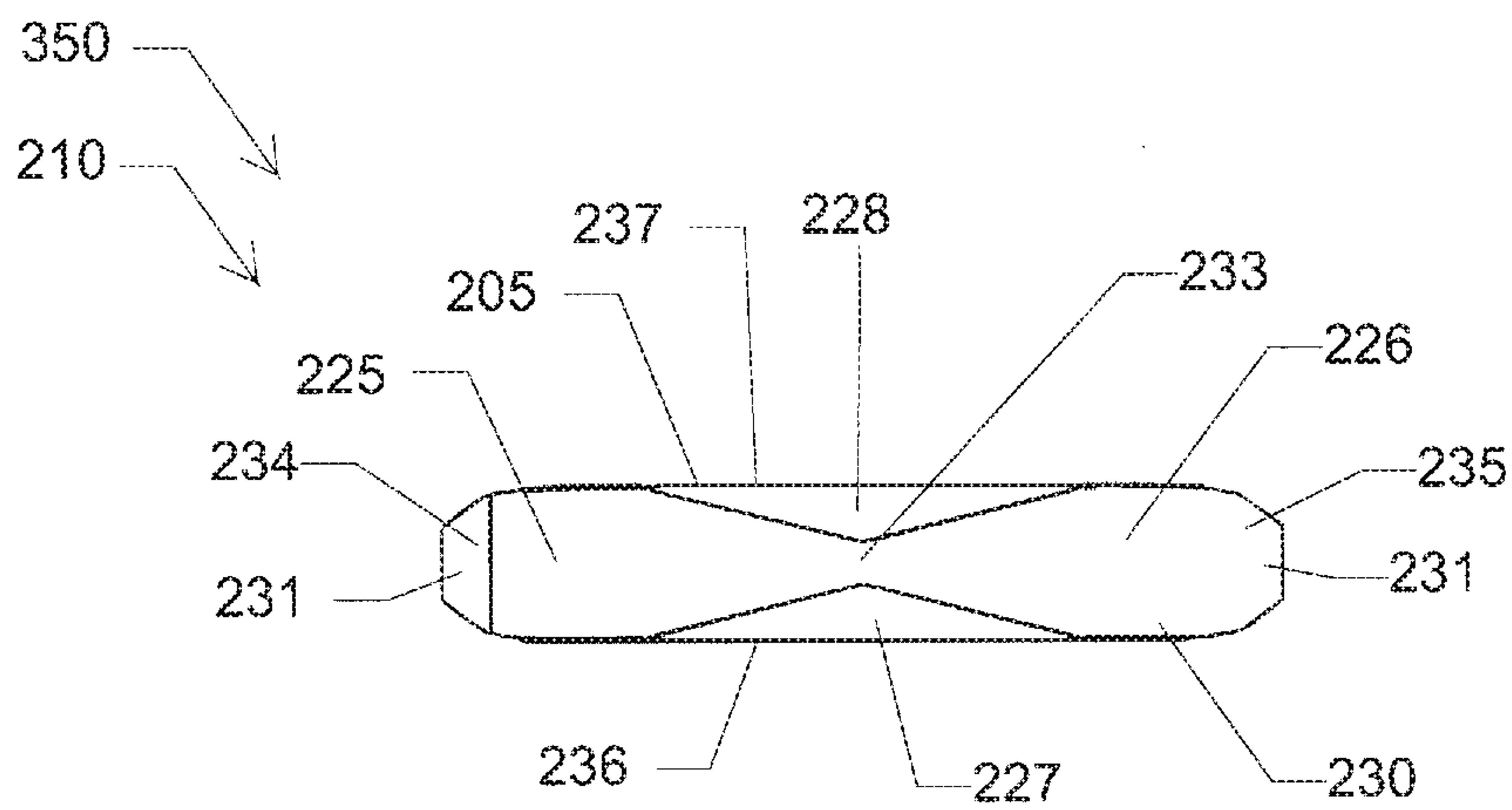
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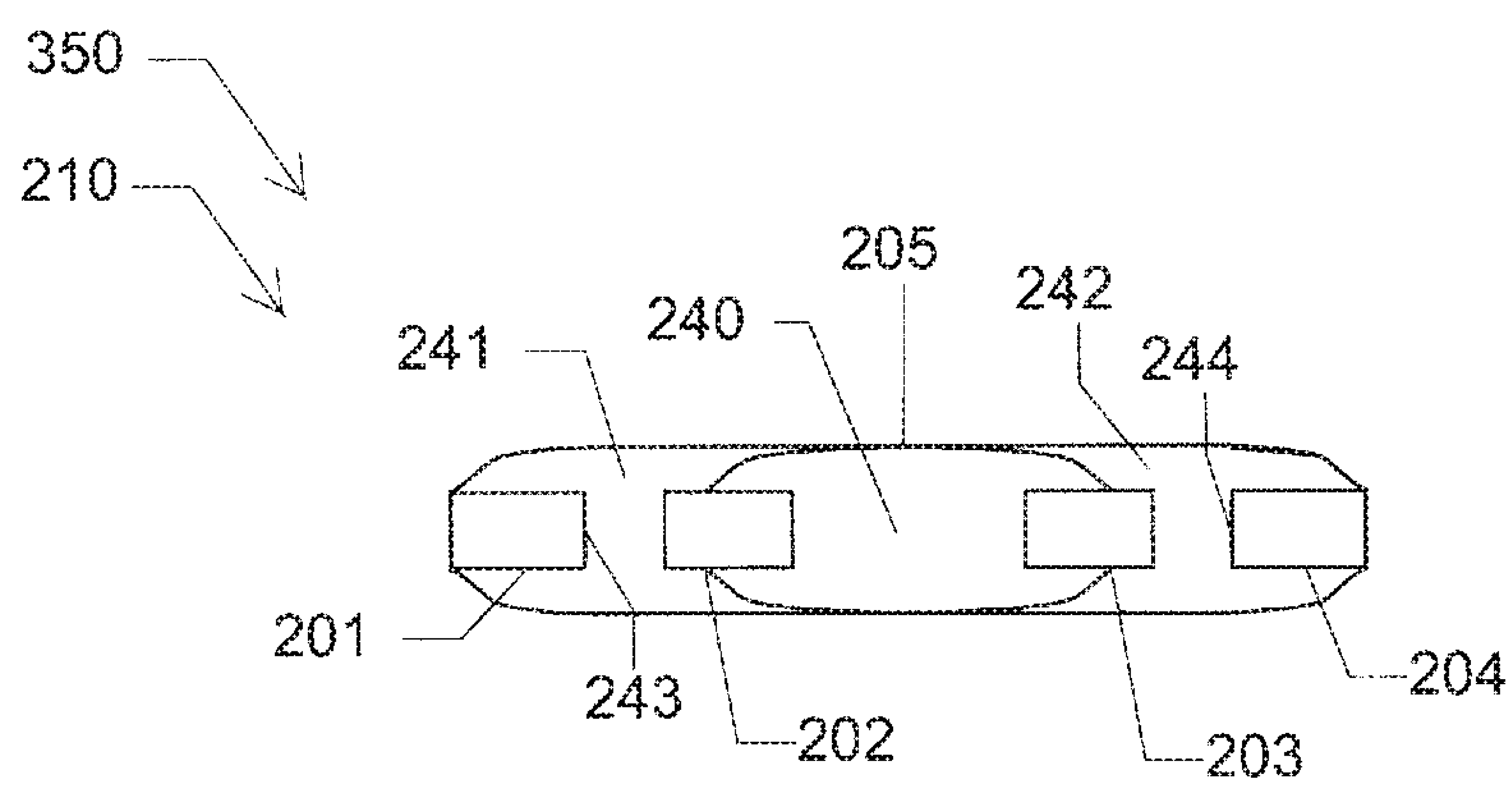
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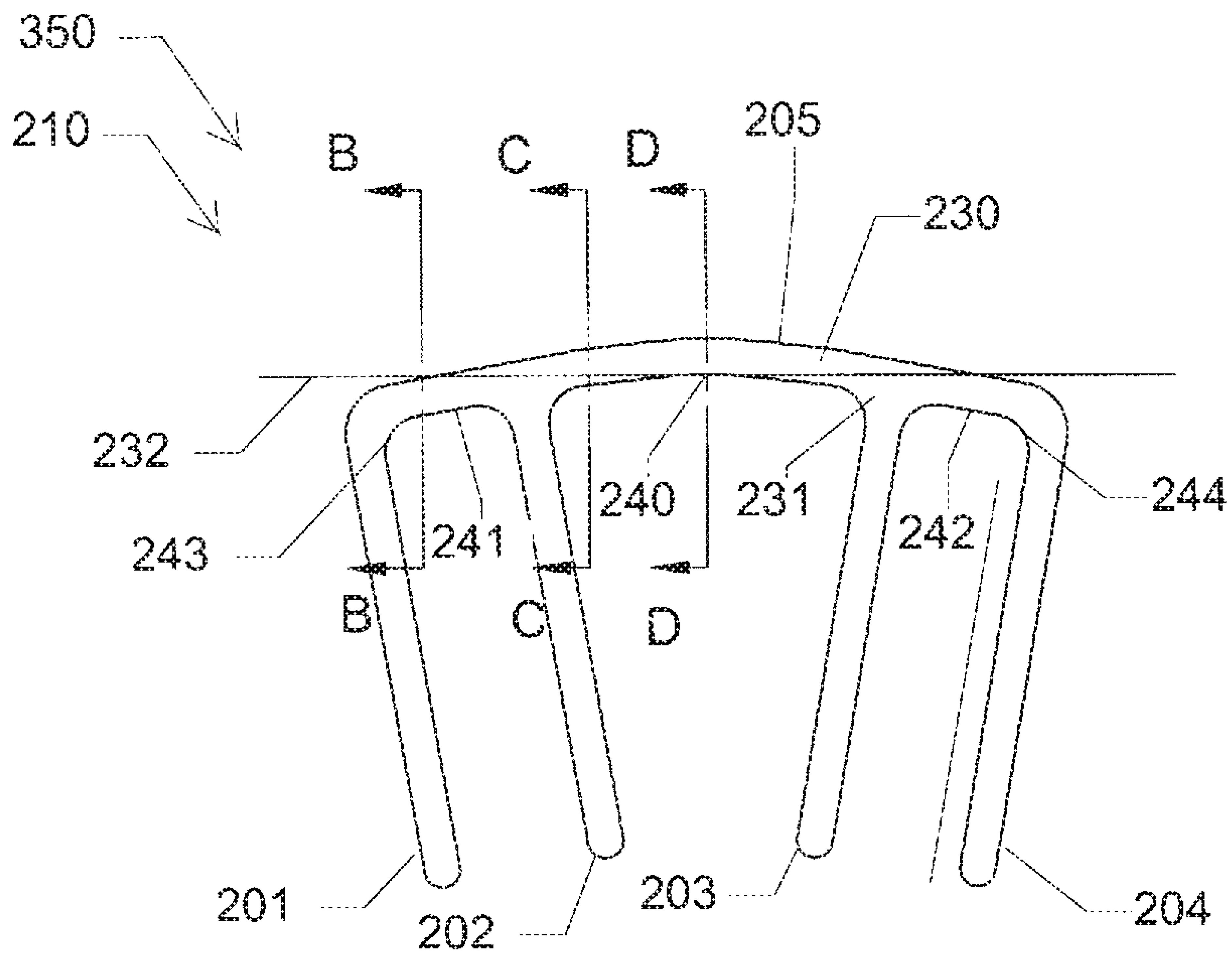

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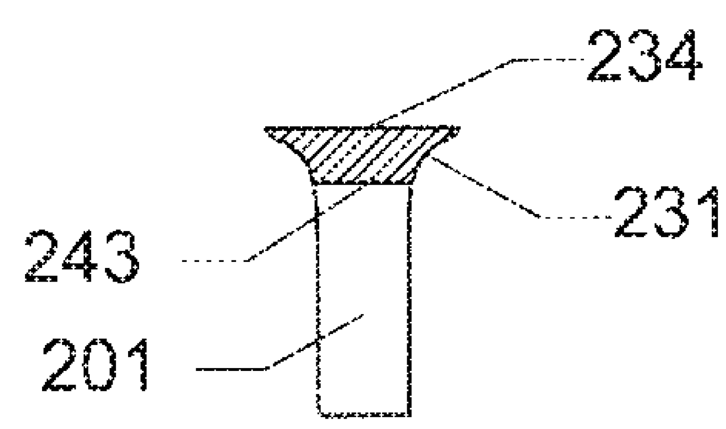

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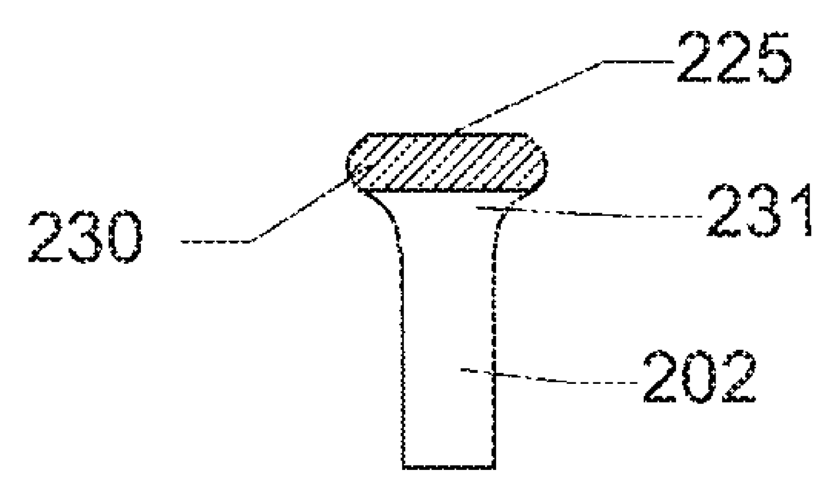

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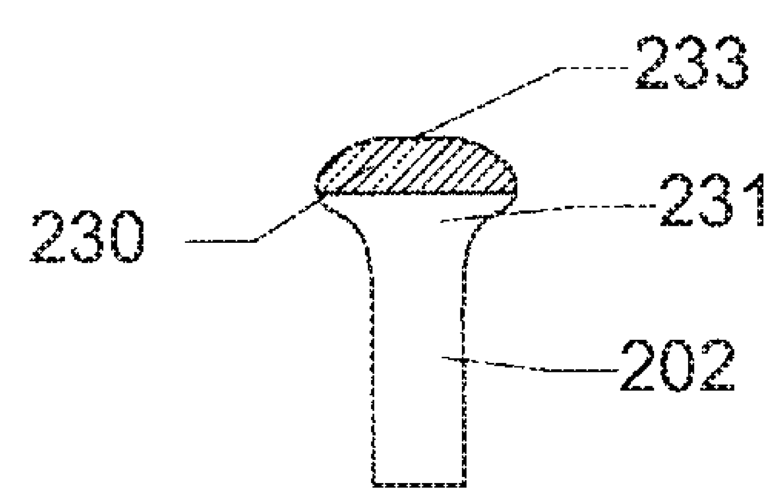

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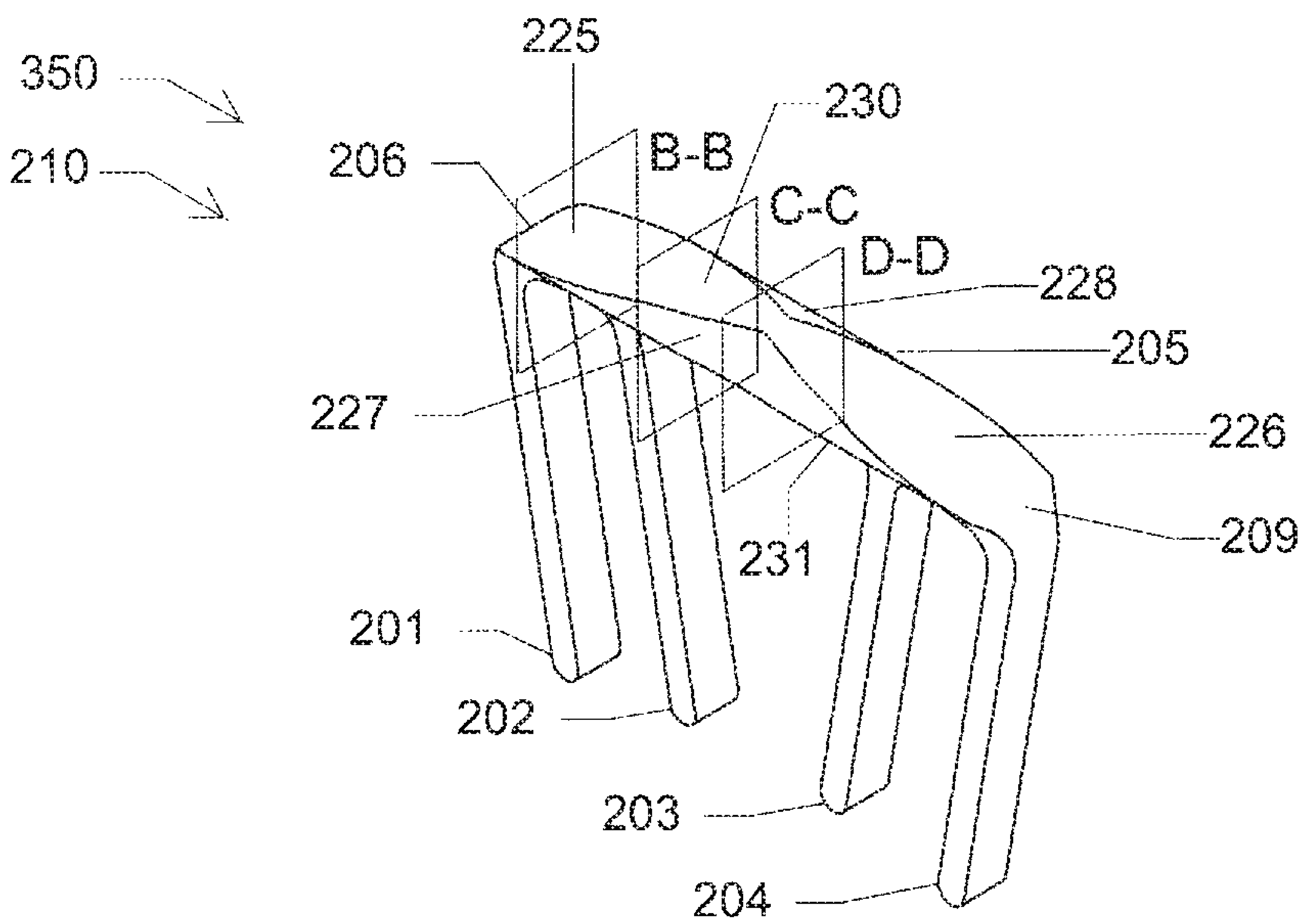

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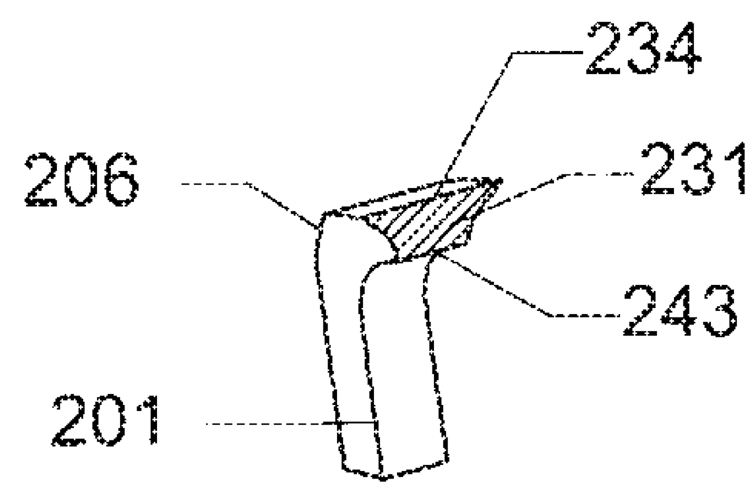

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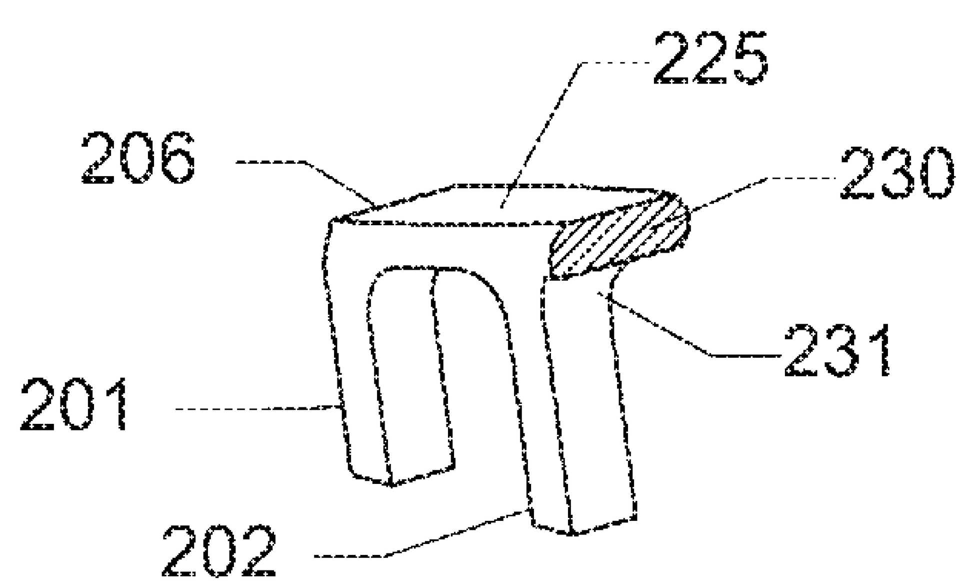

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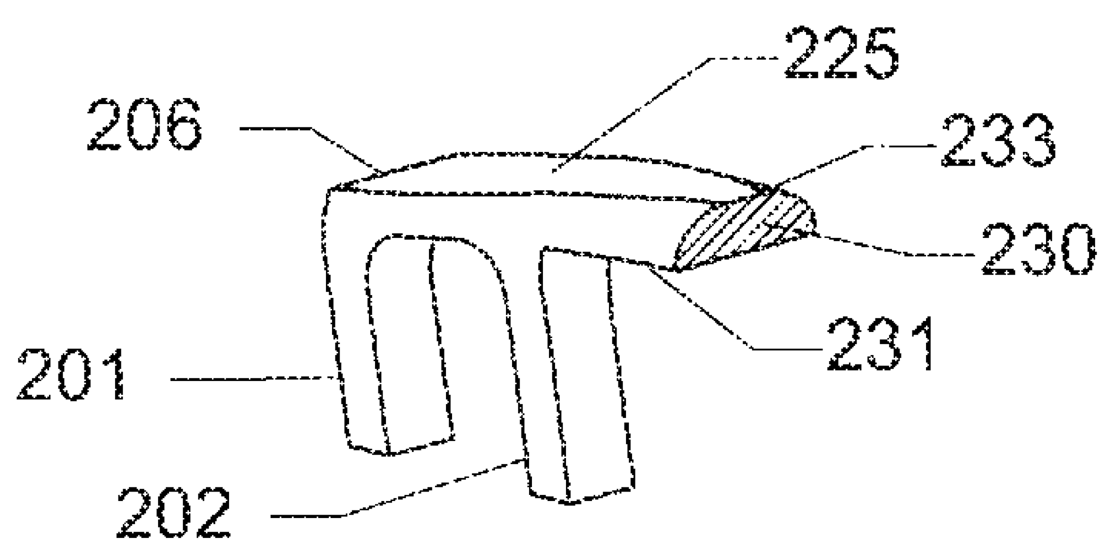

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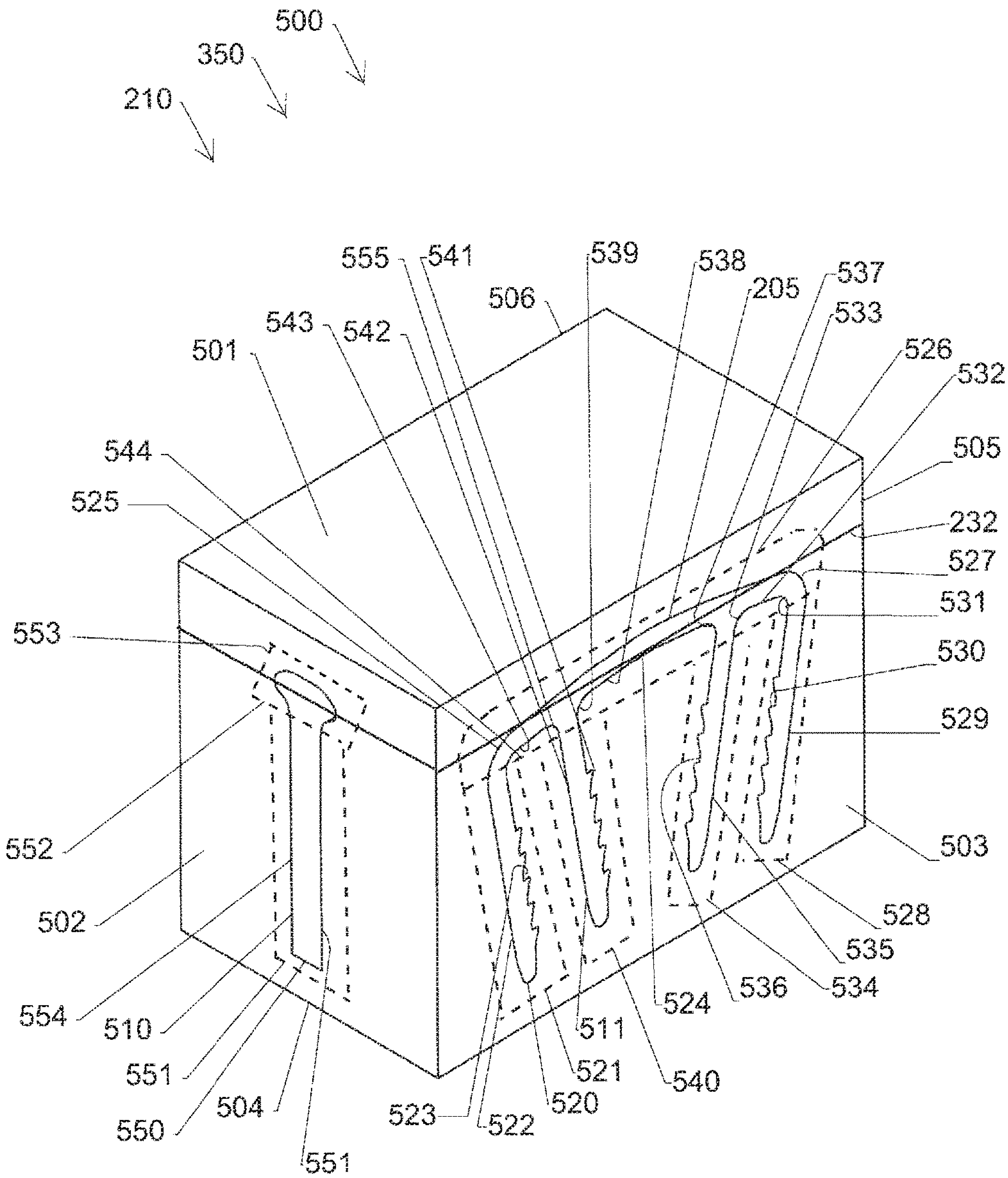
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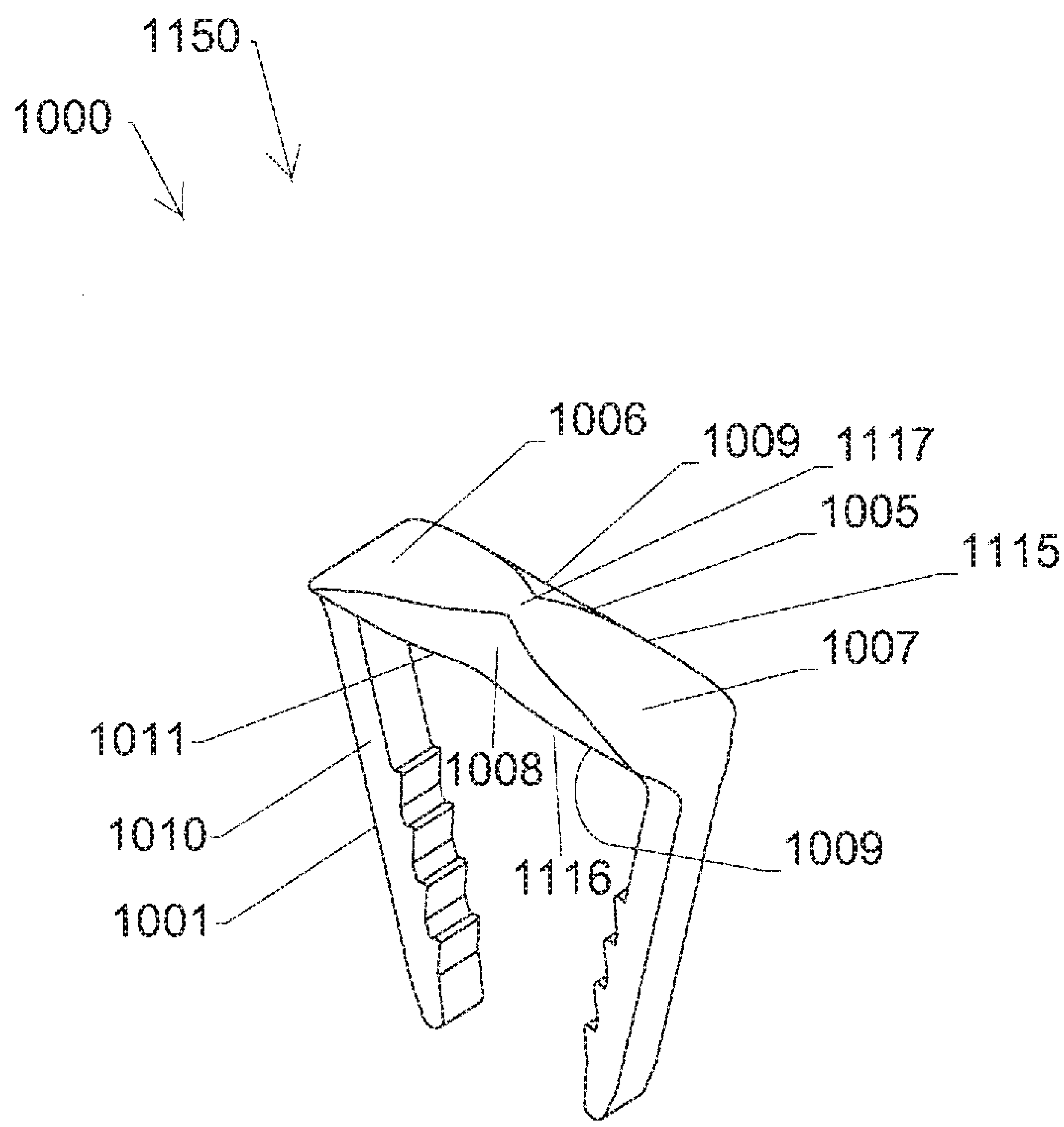
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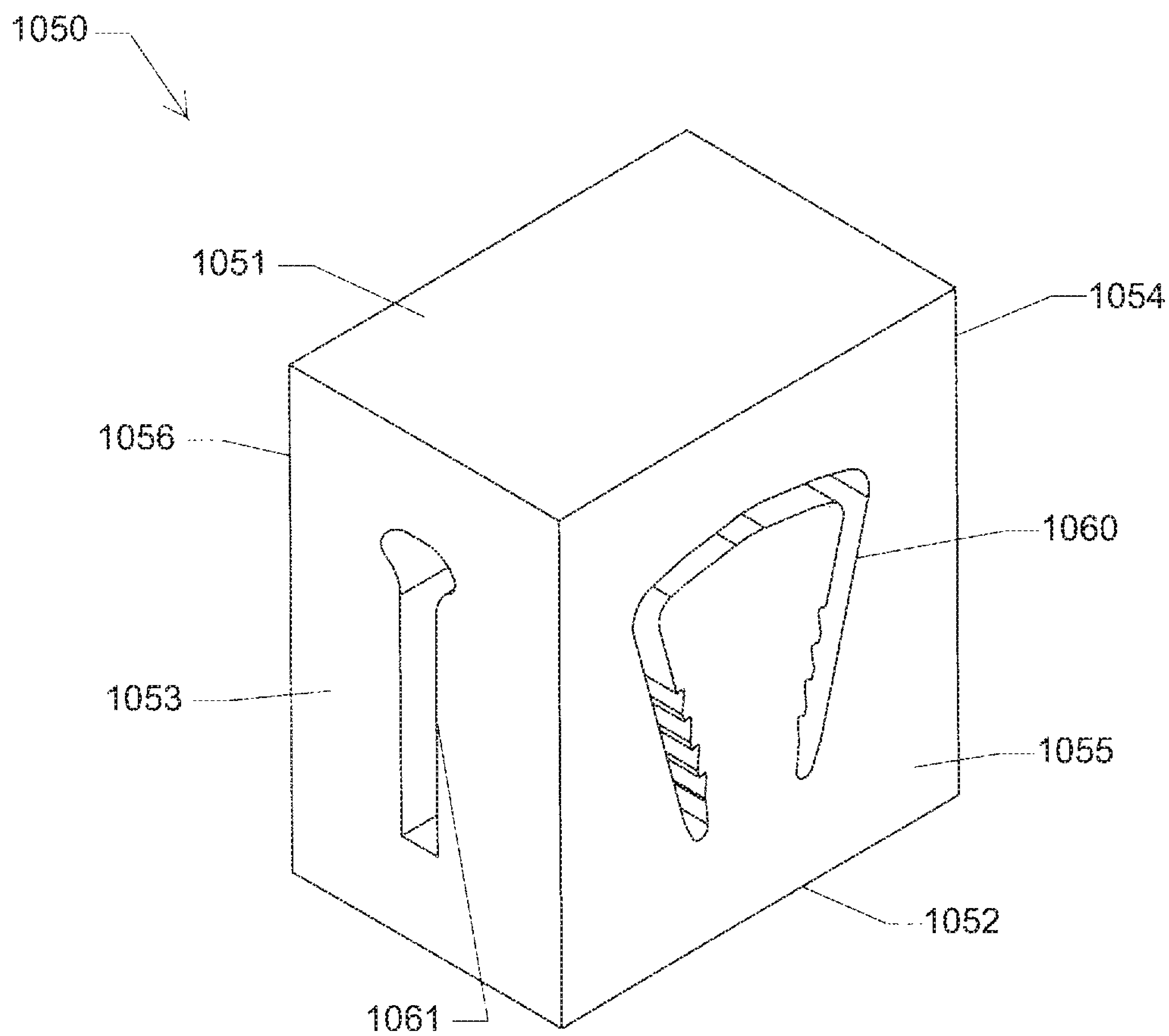
FIG. 28



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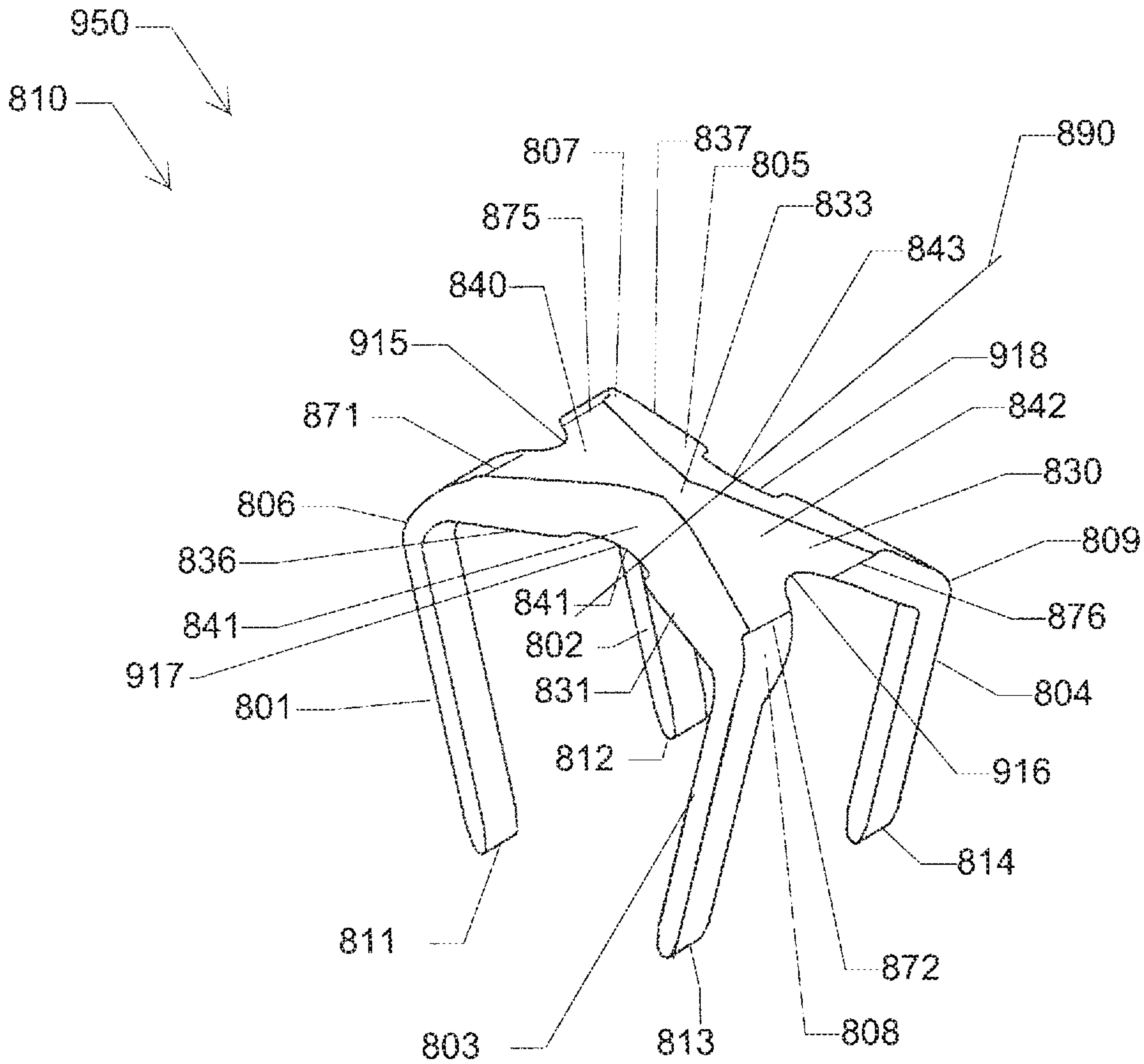
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FIG. 30

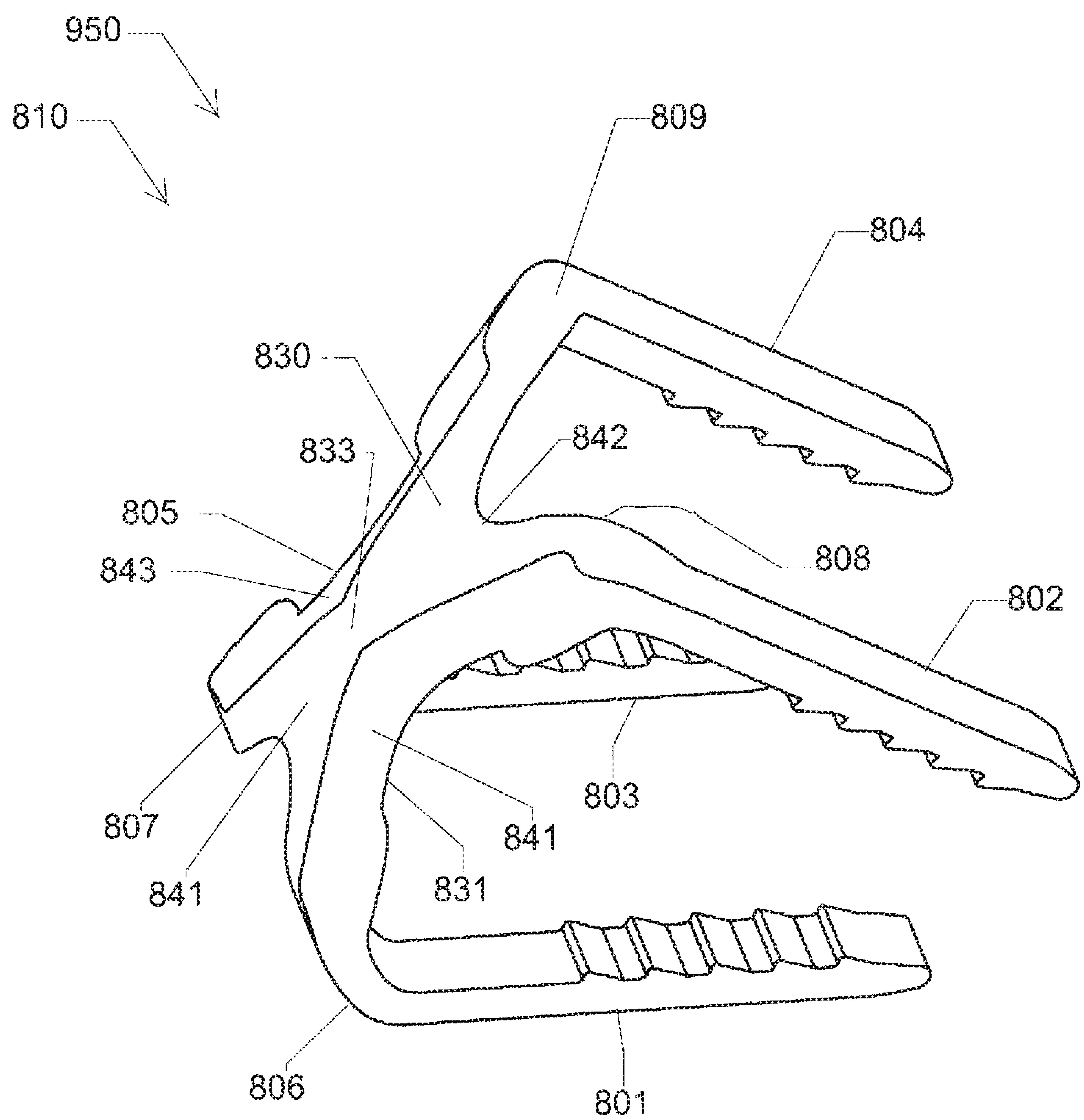
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FIG. 31

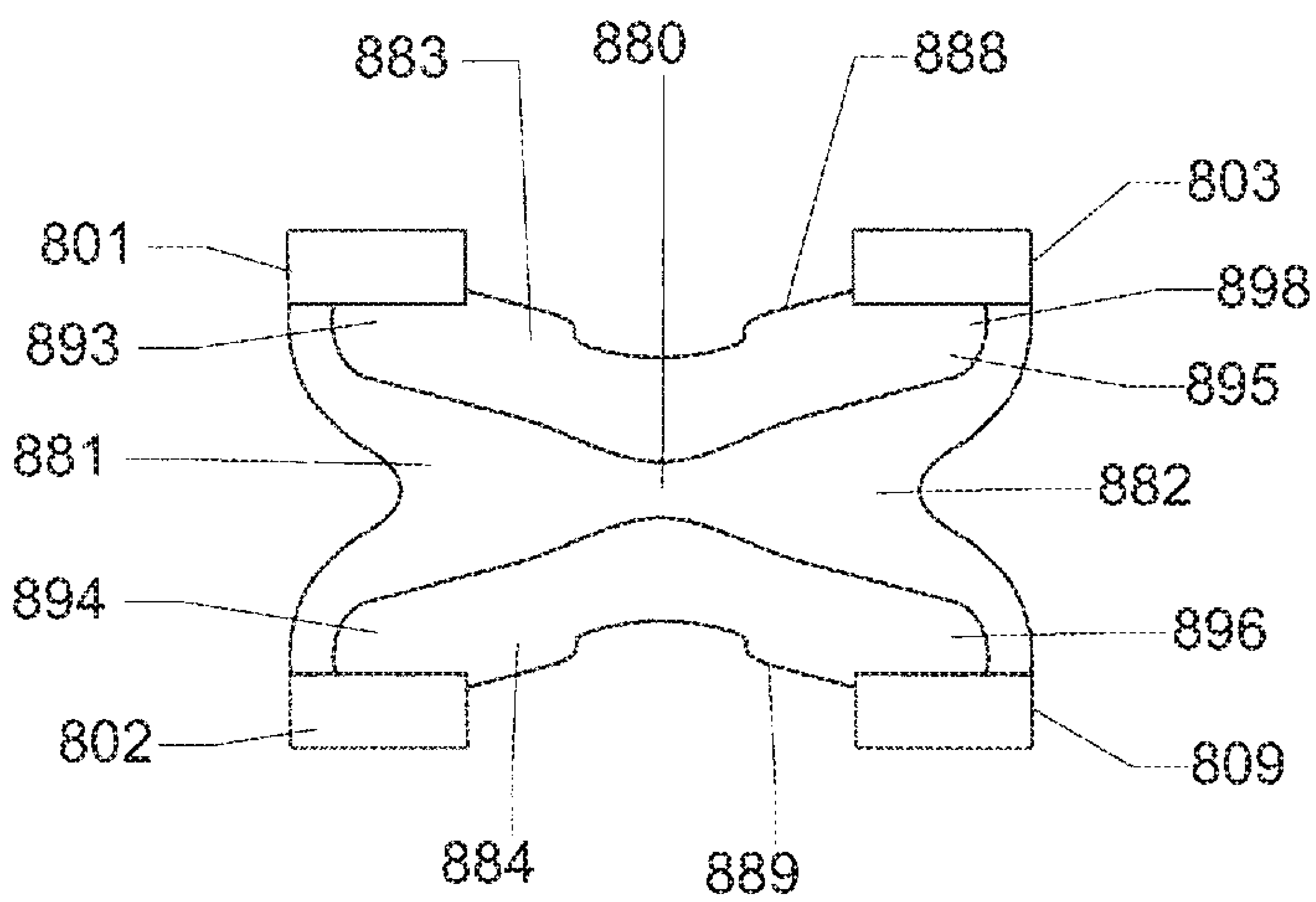


FIG. 32

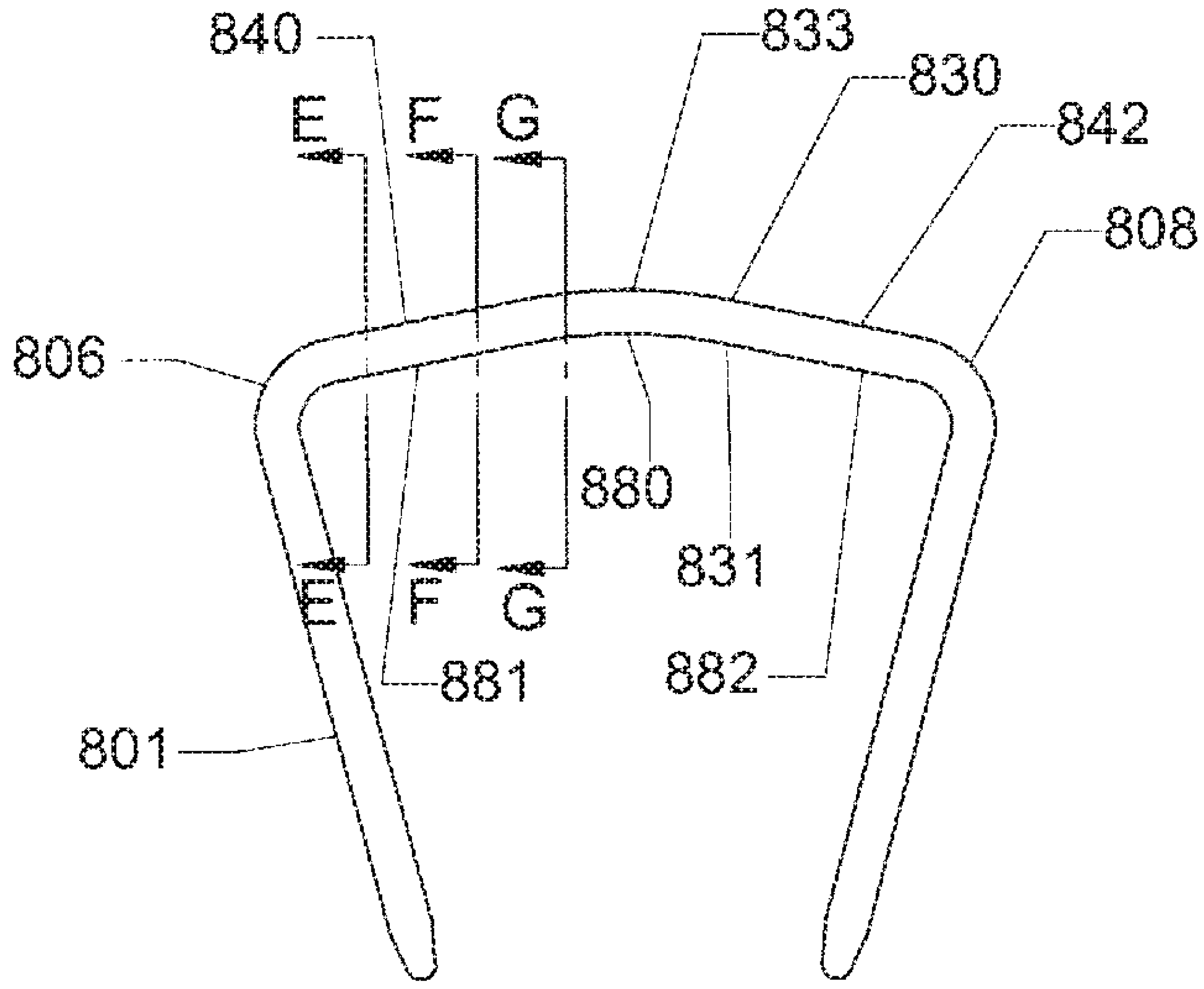


FIG. 33

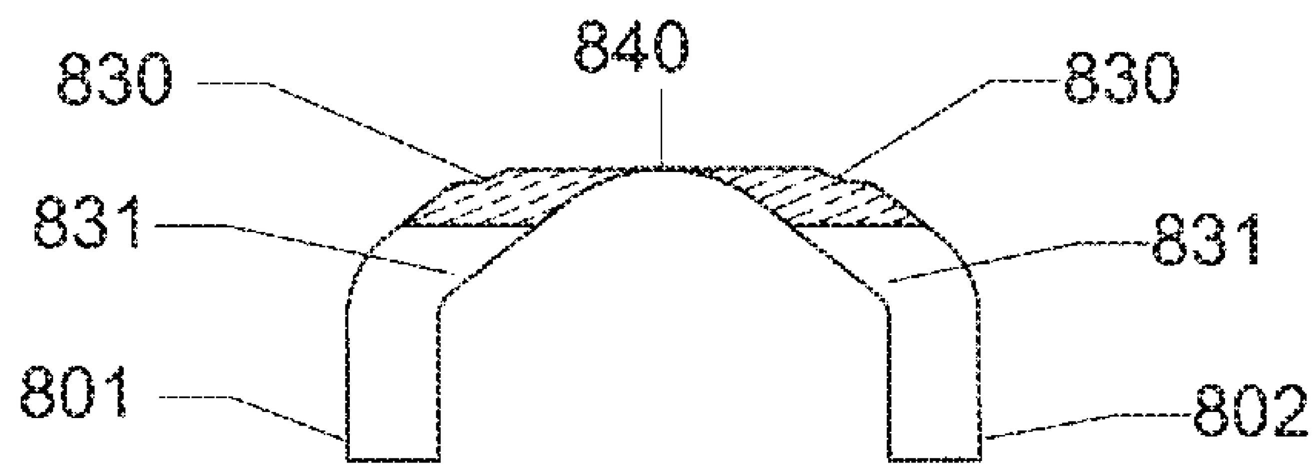


FIG. 34

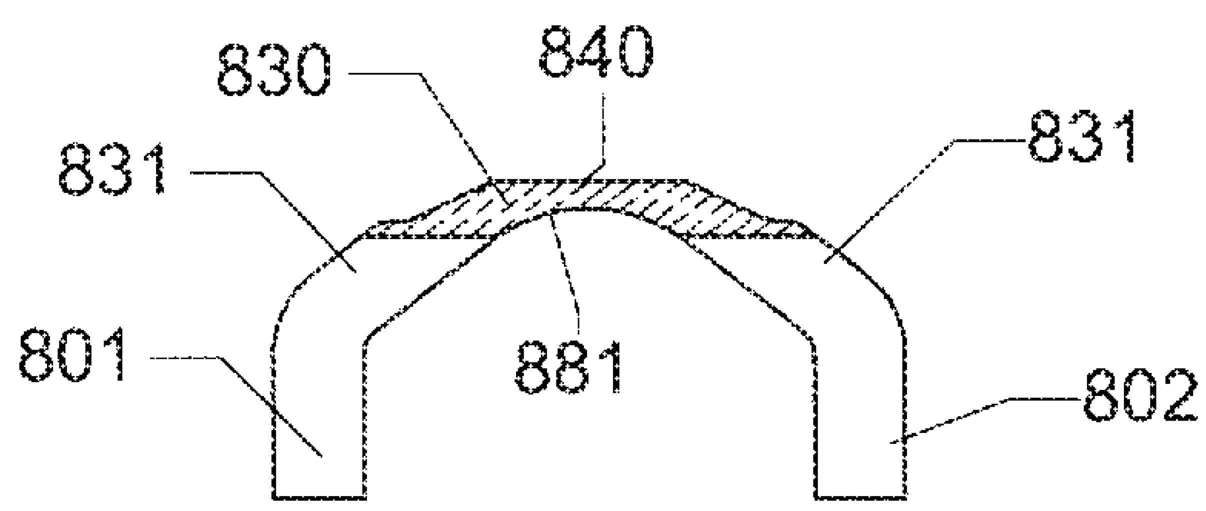


FIG. 35

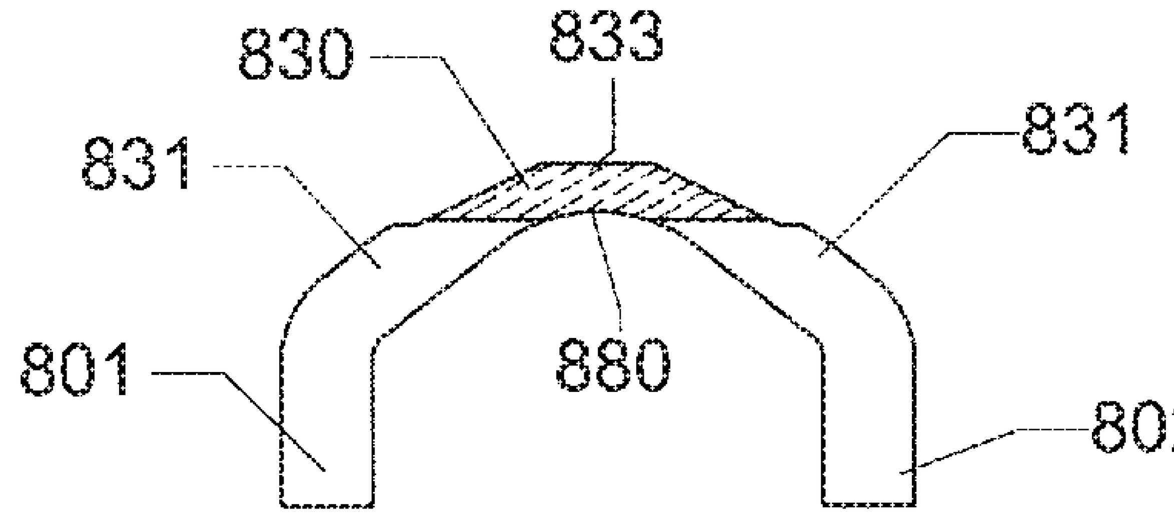


FIG. 36

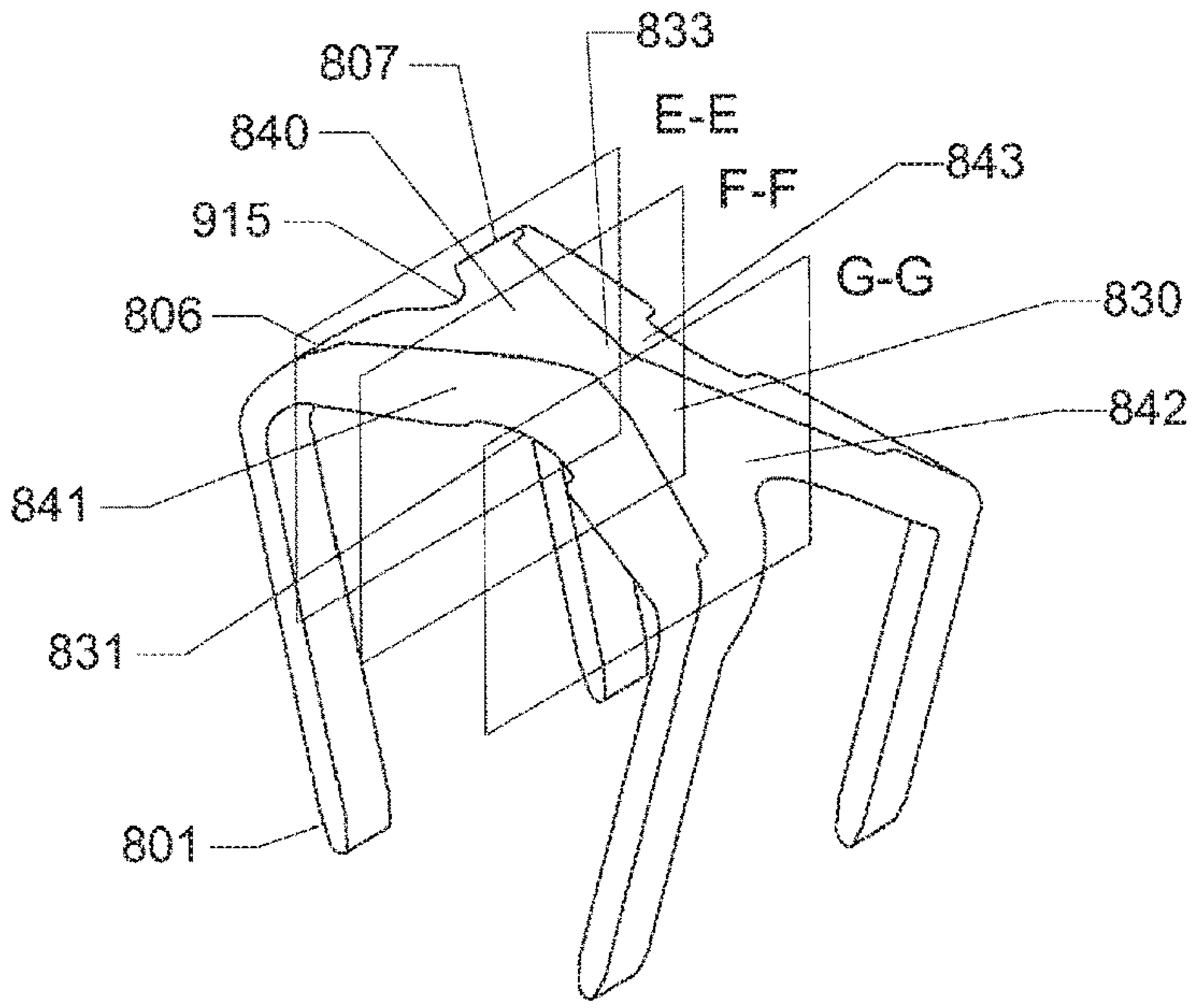


FIG. 37

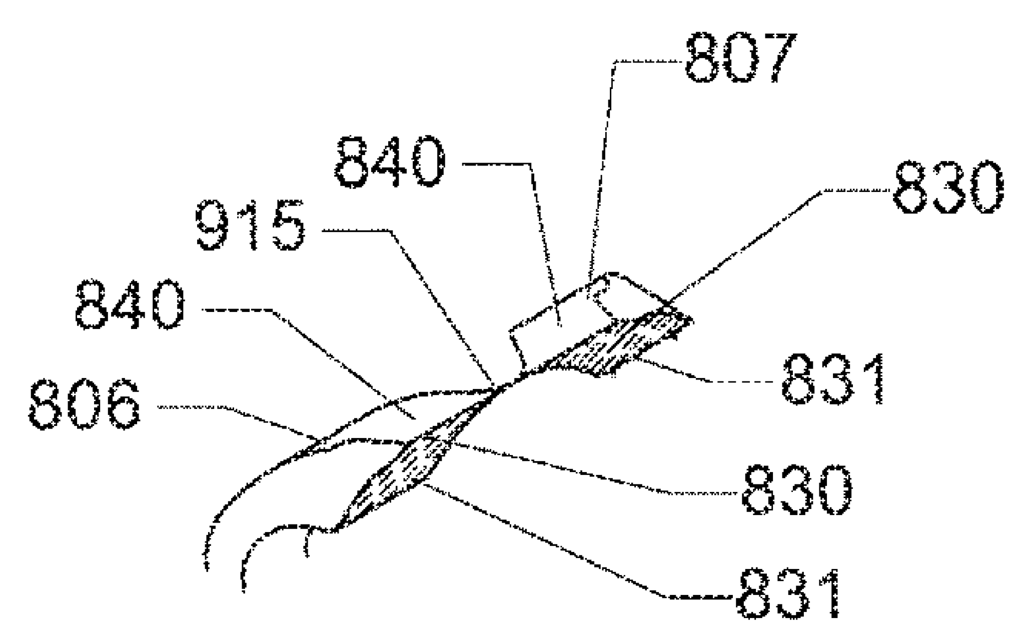


FIG. 38

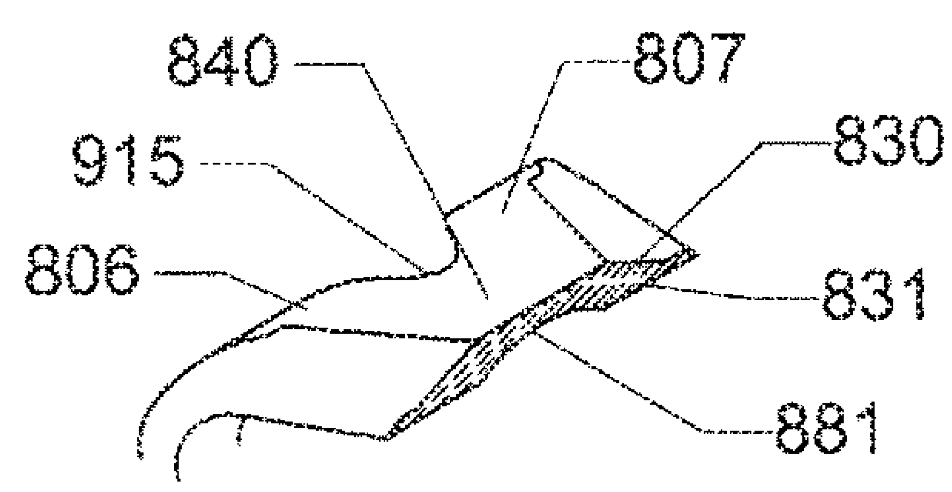
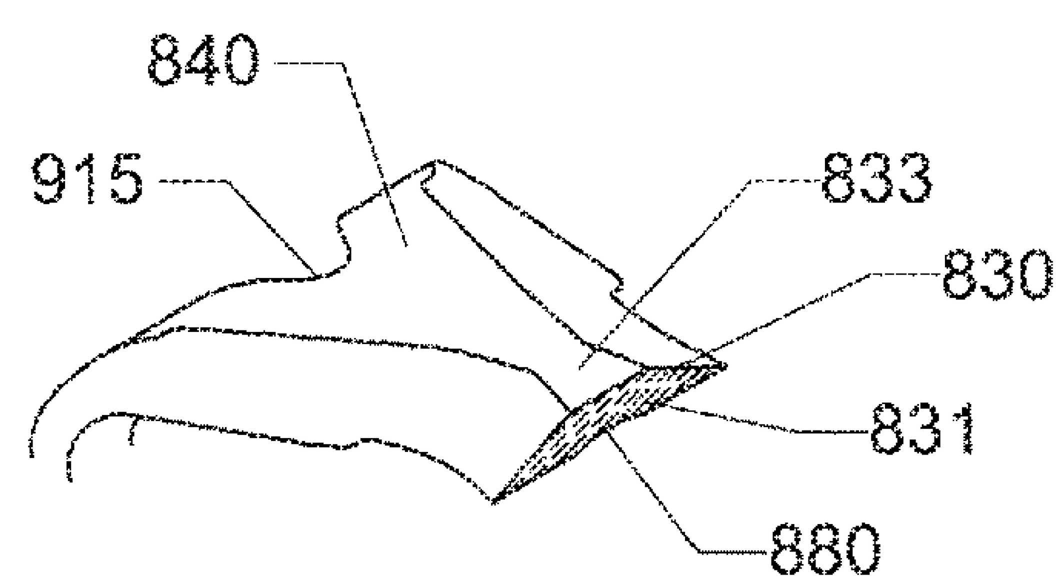


FIG. 39



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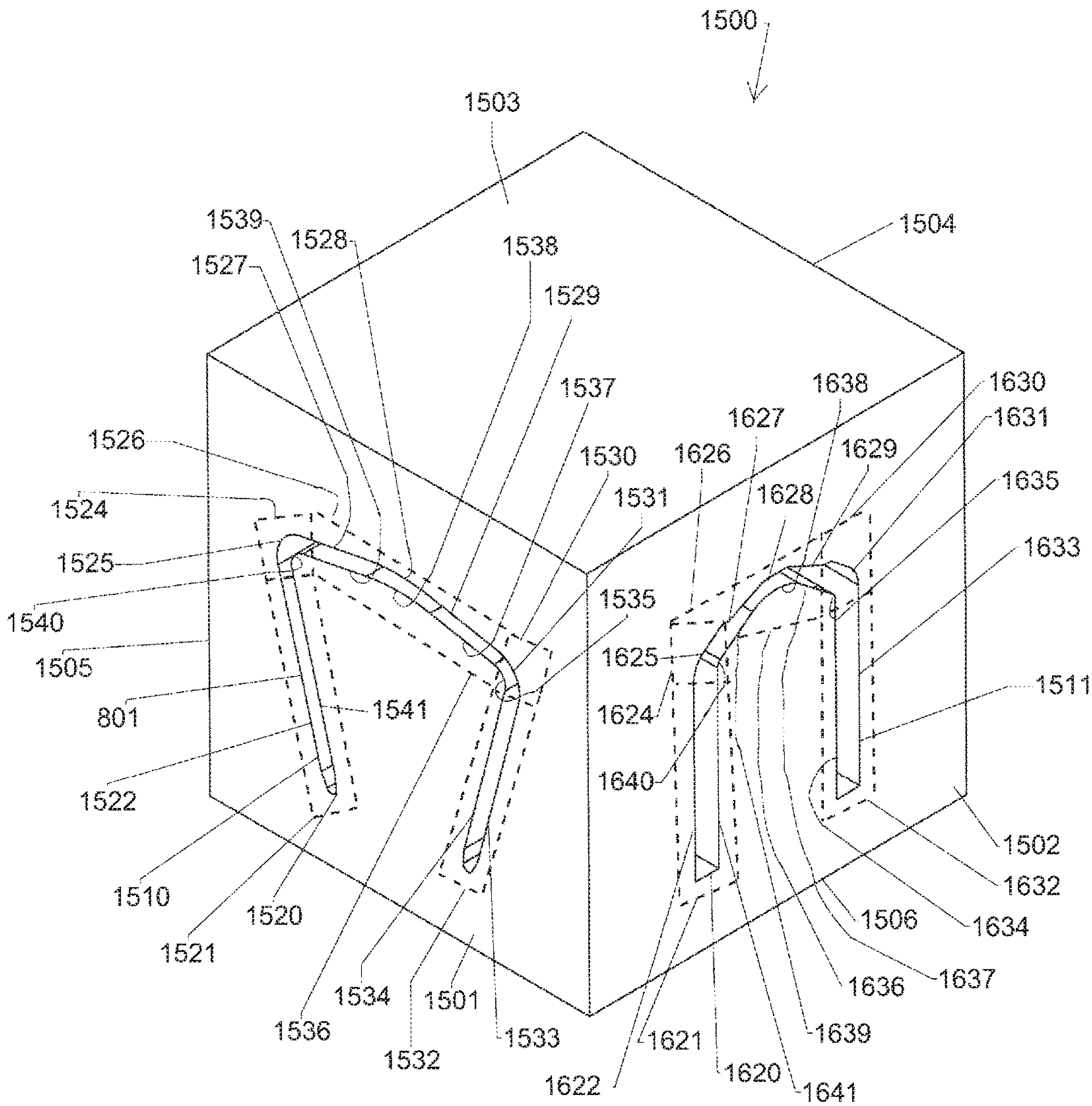
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1634
1636
1637
1639
1621
1622
1620
1641

FIG. 41

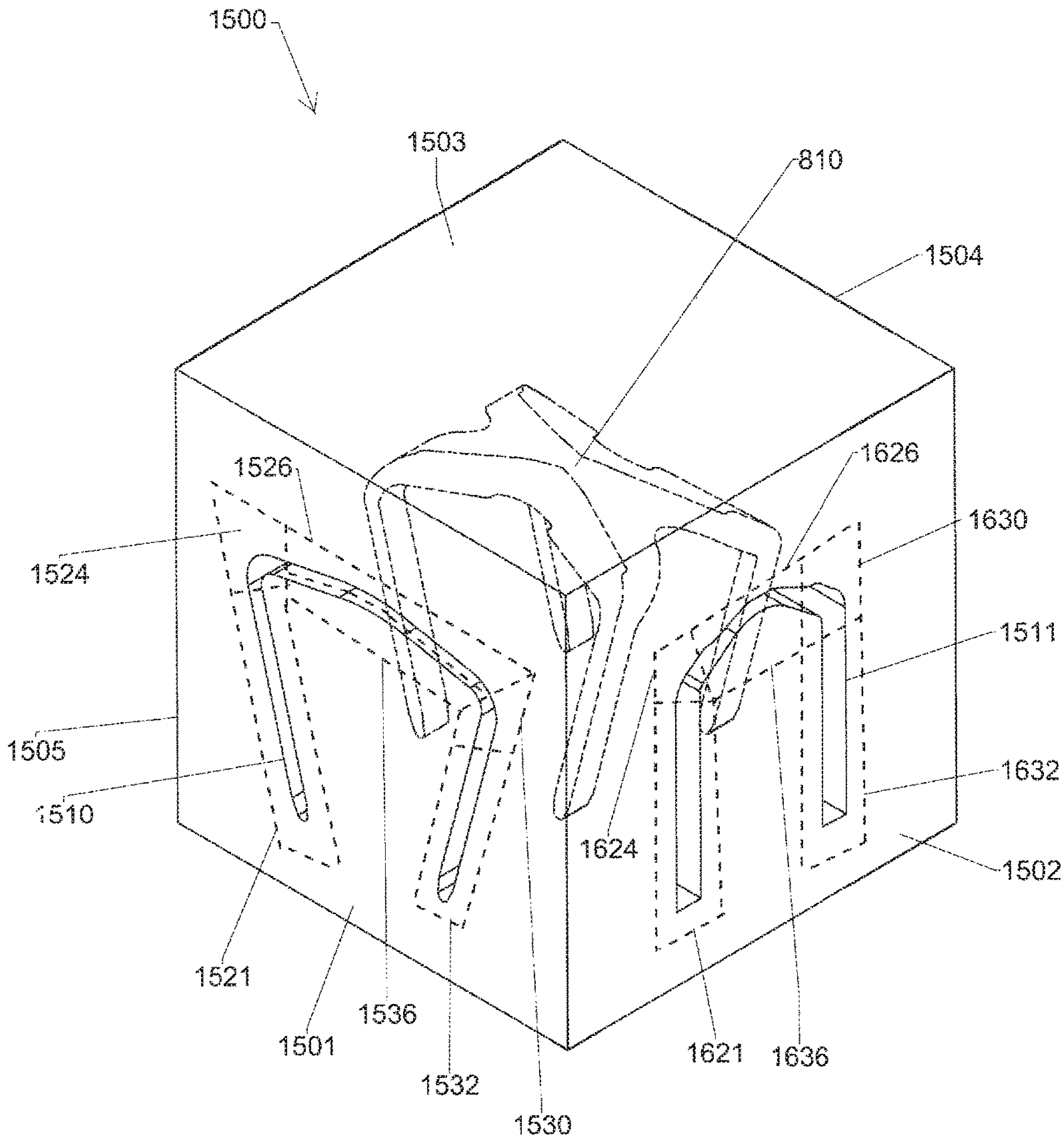
1500
1503
810
1504
1526
1626
1630
1524
1511
1505
1510
1632
1624
1502
1521
1536
1501
1621
1636
1532
1530

FIG. 42

ELASTIC ORTHOPEDIC IMPLANT AND METHOD OF MANUFACTURING THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a method of use and manufacture of an orthopedic implant, and, more particularly, but not by way of limitation, to an orthopedic implant that features a lower profile, beveled edges, and more strength than conventional orthopedic implants.

2. Description of the Related Art

Common orthopedic implants for use in fixating bones together include orthopedic staples. Conventional orthopedic staples have a bridge that connects two or more legs. To fixate bones during surgery, the surgeon drills holes in two bones, or two bone fragments, and then inserts the legs of the orthopedic staple into the holes. The legs can be smooth or have barbs to resist pull out from the bone. Orthopedic implants for use in fixating bones together include several types. Conventional rigid orthopedic staples have a bridge connecting two or more legs and do not create any lasting compression of the two bones. Improvements on conventional rigid orthopedic staples are orthopedic staples made from a shape memory material such as nitinol.

Orthopedic staples made from a shape memory material include a bridge connecting two or more legs wherein the legs converge towards one another at the tips. The advantage of shape memory orthopedic staples is that they can create lasting compression between bones or bone fragments. Specifically, shape memory orthopedic staples can be temporarily distorted within their elastic strain limits so that the legs are parallel. Having the legs parallel allows the staple implant to be inserted into two bones or bone fragments. After insertion and upon release, and, if necessary upon heating to the proper temperature, the implant will return to its converging shape and thus squeeze the two bones or bone fragments together thereby creating lasting compression.

FIGS. **1-6** illustrate a prior art shape memory implant **10**. The bridge **3** of the implant **10** has four surfaces, a top surface **20**, two side surfaces **21** and **22**, and a bottom surface **23**. The top surface **20** has a surface normal that points upwards, the bottom surface **23** has a surface normal that points downwards, and the side surfaces **21** and **22** have surface normals that are directed orthogonal to the surface normal of top surface **20**. FIGS. **1** and **2** illustrate the implant **10** in an insertion position **100** with legs **1** and **2** parallel to each other and perpendicular to a bridge **3**. As illustrated in FIG. **2**, angle alpha is approximately 90 degree in the insertion position **100**. Furthermore, in the insertion position, the bridge **3** is a uniform height from corner **4** to corner **5**.

FIG. **3** illustrates the implant **10** in an implanted position **150** wherein leg tips **6** and **7** of the legs **1** and **2** are closer together than the insertion position **100**. Specifically, the corners **4** and **5** produce rotational torque to squeeze the tips **6** and **7** together thereby creating a compressive force between the legs **1** and **2**. Furthermore, in the implanted position, the bridge **3** of implant **10** is slightly arched helping to create a compressive force between legs **1** and **2**.

Whether the implant **10** is in the insertion position **100** or the implanted position **150**, the bridge **3** of the implant **10** has a uniform thickness from end to end. FIGS. **4** and **5** illustrate a top view and a side view of the implant **10** showing the bridge **3** has an approximate rectangular cross-section. In particular, the cross-section of the bridge **3** is uniform from a corner **4** to a corner **5** and across the length of the bridge **3**. The uniform thickness from end to end of the bridge **3** creates sharp edges that may be felt as a rectangular lump by the patient after surgery.

FIG. **6** illustrates the implant **10** implanted into a bone **200**. The implant **10** is placed into the insertion position **100** and inserts into the bone **200**. The implant **10** then moves from the insertion position **100** to the implanted position **150** due to stored energy in the shape memory implant **10**. After the implant **10** is implanted into the bone **200** the top surface **20** of the bridge and the side surfaces **21** and **22** form a rectangular lump that would be present on top of the bone **200** and under the soft tissue of a patient.

FIGS. **7-9** illustrate a prior art shape memory implant **50** disclosed in U.S. Pat. No. D705,930S. The implant **50** includes legs **56** and **57** connected with abridge **51**. The bridge **51** of the implant **50** has four surfaces, atop surface **52**, two side surfaces **53** and **54**, and a bottom surface **55**. The top surface **52** has a surface normal that points upwards, and the bottom surface **55** has a surface normal that points downwards. The top surface **52** is wider than the bottom surface **55** such that the side surfaces **53** and **54** taper from the top surface **52** towards the bottom surface **55**. As a result, the bridge **51** is wider than the legs **56** and **57**, which increases the strength of the implant **50**.

FIGS. **7-9** illustrate the implant **50** in an implanted position wherein leg tips **59** and **60** of the legs **56** and **57** are closer together than in an insertion position where the legs **56** and **57** are parallel to each other and perpendicular to abridge **51**. Specifically, in the implanted position, the corners **61** and **62** produce rotational torque to squeeze the tips **59** and **60** together thereby creating a compressive force between the legs **56** and **57**. Furthermore, in the implanted position, the bridge **51** of implant **50** is slightly arched helping to create a compressive force between legs **56** and **57**.

Whether the implant **50** is in the insertion position or the i ted position, the bridge **51** of the implant **50**) has a uniform thickness from end to end. In particular, the cross-section of the bridge **51** is uniform from the corner **61** to the corner **62** and across the length of the bridge **51**. The uniform thickness from end to end of the bridge **51** creates edges that may be felt as a lump by the patient after surgery.

FIG. **10** illustrates a prior art implant **610** in an insertion position **750**. The implant **610** includes a bridge **605** and four legs **601-604**. The bridge **605** spans and connects the four legs **601-604** at corners **606-609**. The bridge **605** of the implant **610** has a uniform height between the four legs **601-604**, and the top surface has a normal that is directed vertically upwards. The bridge **605** of the implant **610** has across-sectional profile that is substantially similar to the bridge **3** of the implant **10** in that the bridge **605** of the implant **610** has a uniform thickness from end to end. As such, the implant **610** like the implant **10** creates sharp edges that may be felt as a rectangular lump by the patient after surgery.

In addition to the prior art staple described above, there are other shape memory orthopedic staples on the market today. The Stryker Easy Clip™ implant is a nitinol implant with abridge connecting two converging legs. It is mechanically distorted so that the legs are in a parallel shape via a metal instrument. The same metal instrument is used to insert the legs into bone, and then releases the staple. U.S. Pat. No. 8,584,853 B2 and related U.S. Pat. No. D 705,930S, U.S. Pat. No. D691,720S, and U.S. Pat. No. D706,927S, as previously described with respect to FIGS. **7-9**, are nitinol implants with a bridge that connects two or more converging legs. These implants are pre-loaded onto insertion tools that maintain the leas in parallel position for later insertion into bone. The Stryker Easy Clip™ and the products disclosed in U.S. Pat. No. 8,584,853 B2; U.S. Pat. No. D 705,930S; U.S. Pat. No. D691,720S; and U.S. Pat. No. D706,927S are examples of nitinol implants wherein the bridge has a uniform width and thickness across the entire implant. Specifically, a cross section taken orthogonal to the bridge at any location between the legs would show the same cross-section height.

There are various methods of manufacturing elastic shape memory implants such as the Stryker Easy Clip™ as well as the implants **10**, **50**, and **610**. The Stryker Easy Clip™ can be manufactured by electrical discharge machining from a flat plate. The implants **10** and **50** can be manufactured by electrical discharge machining or a similar method from a billet. The implant **610** can be manufactured from a flat sheet of material. Specifically, the implant **610** is cut from a flat sheet and the legs **601-604** are then bent into the final shape. Regardless, of whether implants are manufactured using electrical discharge machining, or manufactured from a flat plate or billet of material, the implants **10**, **50**, and **610** feature a uniform bridge thickness such that the patient would feel the full thickness of bridge at all locations.

As described above, the existing prior art orthopedic implants have bridges with uniform thickness from end to end after they are manufactured. In particular, a cross section taken orthogonal to the bridge at any location between the legs would show the same cross-section height. This design can potentially create a bulge or protuberance after surgery that can be fell by a patient as a lump under their skin. After manufacture, and to mitigate the problems associated with having a bridge with uniform thickness, the edges of the prior a implants may he rounded by mechanical tumbling or acid etching. However, even after mechanical tumbling or acid etching the surfaces that make up the bridge are orthogonal to each other and the bridge still has a uniform thickness that can potentially be felt by a patient. Furthermore, mechanical tumbling or acid etching an implant after manufacture increases costs.

Accordingly, a shape memory implant design and a method of manufacture thereof that has a lower profile and tapered shape at the time of manufacturing, does not have orthogonal bridge surfaces, has greater strength than prior art implants, and creates less of a bulge or protuberance under the skin would be beneficial.

SUMMARY OF THE INVENTION

In accordance with the present invention, an elastic orthopedic staple implant includes a bridge that connects two or more lees. The implant has a natural shape with the two or more legs converging towards each other. Each of the legs can either be smooth, or have barbs to increase pull-out resistance from bone. The legs can either be homgeneous with the bridge, such that it is made from the same material, or the legs could be screws and made from a different material.

The bridge design of the implant has slanted surfaces that result in tapered upper and lower surfaces. These surfaces are not orthogonal to each other, which, therefore, results in a more smoothed composite surface. The tapered upper surface of the bridge results in a cross-sectional thickness that is lower than a conventional implant, and less of protuberance to a patient. Similarly, the lower surface of the bridge is tapered to allow the implant to lie more flat. The bridge design of the implant is also such that the bridge is wider than the legs. This allows for the bridge to have greater bending strength than a comparable prior art implant, because most prior art implants have a bridge width that matches the width of the leg.

The implant can be elastically deformed to a temporary insertion shape with legs that are parallel to each other. One way of elastically deforming the implant is done by deforming the legs relative to the bridge, which in effect increases an acute angle between the leg and bridge to become a right angle. By stretching the converging legs simultaneously, all of the acute angles become right angles and are thus parallel. Alternatively, the implant can be deformed by stretching the bridge. In this case, the angles between legs and bridge are all right angles, and the stretching of the bridge rotates all legs from converging to parallel position simultaneously.

The elastic implant of this invention can be made from a solid billet of material. The material can be cut from two orthogonal directions, using a single continuous cutting motion from each of the two directions. When finished, the implant with advanced bridge design and superior strength can be retrieved from the solid billet. The cutting motion for each orthogonal surface is a continuous path with uniform thickness.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view illustrating a shape memory implant according to the prior art.

FIG. **2** is a side view illustrating the shape memory implant according to the prior art with its legs parallel.

FIG. **3** is a side view illustrating the shape memory implant according to the prior art with its legs converging.

FIG. **4** is a top view illustrating the shape memory implant according to the prior art.

FIG. **5** is cross-sectional side view taken along lines A-A in FIG. **4** illustrating the shape memory implant according to the prior art.

FIG. **6** is a perspective view illustrating shape memory implant according to the prior art after implantation into a bone.

FIG. **7** is a perspective view illustrating a shape memory implant according to the prior art.

FIG. **8** is a front view illustrating the shape memory implant according to the prior art.

FIG. **9** is a side view illustrating the shape memory implant according to the prior art.

FIG. **10** is a perspective view illustrating a shape memory implant according to the prior art.

FIGS. **11** and **12** are a perspective views illustrating an implant according to a first embodiment with its legs converging.

FIG. **13** is a side view illustrating the implant according to the first embodiment with its legs converging.

FIG. **14** is a side view illustrating the implant according to the first embodiment with its legs parallel.

FIG. **15** is a perspective view illustrating the implant according to the first embodiment implanted in a bone.

FIG. **16** is an end view illustrating the implant according to the first embodiment.

FIG. **17** is a top view illustrating the implant according to the first embodiment.

FIG. **18** is a bottom view illustrating the implant according to the first embodiment.

FIG. **19** is a side view illustrating the implant according to the first embodiment with its legs converging.

FIG. **20** is cross-sectional side view taken along lines B-B in FIG. **19** illustrating the implant according to the first embodiment.

FIG. **21** is cross-sectional side view taken along lines C-C in FIG. **19** illustrating the implant according to the first embodiment.

FIG. **22** is cross-sectional side view taken along lines D-D in FIG. **19** illustrating the implant according to the first embodiment.

FIG. **23** is a perspective view illustrating the implant according to the first embodiment with its legs converging.

FIG. **24** is cross-sectional side view taken along lines B-B in FIG. **23** illustrating the implant according to the first embodiment.

FIG. **25** is cross-sectional side view taken along lines C-C in FIG. **23** illustrating the implant according to the first embodiment.

FIG. **26** is cross-sectional side view taken along lines D-D in FIG. **23** illustrating the implant according to the first embodiment.

FIG. **27** is a perspective view illustrating a billet of raw material used for cutting the implant according to the first embodiment.

FIG. **28** is a perspective view illustrating an implant according to a second embodiment with its legs converging.

FIG. **29** is a perspective view illustrating a billet of raw material used for cutting the implant according to the second embodiment.

FIGS. **30** and **31** are a perspective views illustrating an implant according to a third embodiment with its legs converging.

FIG. **32** is a bottom view illustrating the implant according to the third embodiment.

FIG. **33** is a side view illustrating the implant according to the third embodiment with its legs converging.

FIG. **34** is cross-sectional side view taken along lines E-E in FIG. **34** illustrating the implant according to the third embodiment.

FIG. **35** is cross-sectional side view taken along lines F-F in FIG. **34** illustrating the implant according to the third embodiment.

FIG. **36** is cross-sectional side view taken along lines G-G in FIG. **34** illustrating the implant according to the third embodiment.

FIG. **37** is a perspective view illustrating the implant according to the third embodiment with its legs converging.

FIG. **38** is cross-sectional side view taken along lines E-E in FIG. **37** illustrating the implant according to the third embodiment.

FIG. **39** is cross-sectional side view taken along lines F-F in FIG. **37** illustrating the implant according to the third embodiment.

FIG. **40** is cross-sectional side view taken along lines G-G in FIG. **37** illustrating the implant according to the third embodiment.

FIGS. **41** and **42** are perspective views illustrating a billet of raw material used for cutting the implant according to the third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which may be embodied in various forms. Figures are not necessarily to scale, and some features may be exaggerated to show details of particular components or steps.

FIGS. **11-27** illustrate a first embodiment of an elastic implant **210**. The implant **210** is shown in a converging position **350**. The implant **210** can be made from any elastic material. An example of such a material is a shape memory implant made from nitinol. The implant **210** includes a bridge **205** and four legs **201-204**. The bridge **205** connects with the legs **201-204**. Each leg **201-204** has a tip **211-214**, respectively, shown converging towards the middle of the implant **210**. The legs **201-204** are smooth; however, it is possible to include barbs on legs **201-204** to improve the pull-out resistance of the implant **210**. The implant **210** includes corners **206-209** and **215-216**. In the first embodiment, the corners **206-209** store energy when deformed and create a compressive force that moves tips **211-214** towards the center of the implant **210**.

The bridge **205** includes a first upper section **230** and a second lower section **231**. The first upper section **230** is the portion of the bridge **205** that lies above a plane **232** and the second lower section **231** is the portion of the bridge **205** that lies below the plane **232**. The first upper section **230** includes a central surface **233** and first, second, third, and fourth surfaces **225-228**. The central surface **233** may be linear to lower the profile of the first upper section **230**. Alternatively, the central surface **233** may be non-linear to provide a smooth transition from the central surface **233** to each of the first, second, third, and fourth surfaces **225-228**. The first surface **725** is non-linear and tapers from the central surface **233** to a first end transition **234** between the first upper section **230** and the second lower section **231**. The second surface **226** is non-linear and tapers from the central surface **233** to a second end transition **235** between the first upper section **230** and the second lower section **231**. The third surface **227** is non-linear and tapers from the central surface **233** to a first side transition **236** between the first upper section **230** and the second lower section **231**. The fourth surface **228** is non-linear and tapers from the central surface **233** to a second side transition **237** between the first upper section **230** and the second lower section **231**. In the first embodiment, the first, second, third, and fourth surfaces **225-228** each taper from the central surface **233** at an angle of between 5 degrees and 85 degrees when measured from a plane tangent to the central surface **233**. The tapering of the first, second, third, and fourth surfaces **225-228** from the central surface **233** provides the implant **210** with a first upper section **230** that has a smooth composite surface and a non-uniform cross-sectional thickness between the first and second end transitions **234** and **235** as illustrated in FIGS. **21-23** and **25-27**. As a result, the implant **210** includes a low profile and provides less of protuberance to a patient.

The second lower section **231** includes a central surface **240** and first and second surfaces **241** and **242**. The central surface **240** is non-linear to provide a smooth transition from the central surface **240** to each of the first and second surfaces **241** and **242**. The first surface **241** is non-linear and tapers from the central surface **240** to a first leg transition **243** between the second lower section **231** and the leg **201**. The second surface **242** is non-linear and tapers from the central surface **240** to a second leg transition **244** between the second lower section **231** and the leg **204**. The central surface **240** and first and second surfaces **241** and **242** may follow a substantially same non-linear path between the first and second leg transitions **243** and **244**. Alternatively, the curvature of the non-linear path for the central surface **240** may be greater than the curvature of the non-linear paths for the first and second surfaces **241** and **242** in order to lessen the cross-sectional area of the second lower section **231** at the central surface **240**. The non-linear paths followed by each of the central surface **240** and the first and second surfaces **241** and **242** provides the implant **210** with a second lower section **231** that flattens the profile of the implant **210**, resulting in less protuberance to a patient. In the first embodiment, the second low section **231** is wider than the legs **201-204** in order to provide the implant **210** with increased bonding strength.

FIG. **12** illustrates the implant **210** in the converging position **350** and with barbs on legs **201-204**. FIG. **13** is a side view illustrating the implant **210** in the converging position **350**, with legs **201-204** converging to the center, while FIG. **14** is a side view illustrating the implant **210** in an insertion position **300**, with legs **201-204** substantially parallel. As illustrated in FIG. **13**, the bridge **205** has been manufactured such that there are tapers on bridge **205** towards the edges of the bridge, labeled as first, second, third, and fourth surfaces **225-228**. The first, second, third, and fourth surfaces **225-228** result in less protuberance than the prior art implants illustrated in FIGS. **1-11** when implanted in bone, because rather than being orthogonal to each other they are directed at angles that result in a more rounded bridge. In addition, the bridge **205** is wider than the legs **201-204**, such that the implant **210** would be stronger in bending for the same dimension legs than prior a implant **10**.

As illustrated in FIG. **13**, the leg **201** has an angle of gamma relative to the bridge **205**. Similarly, the leg **202** has an angle of delta relative to bridge **205**. The legs **203** and **204** are symmetrical to the legs **201** and **202**. The angles gamma and delta may be 90 degrees in the converging position **350**, however, the angles gamma and delta are typically acute angles less than 90 degrees. If acute, the gamma and delta angles may be the same angle or different angles. The bridge **205** has a bend in the middle that results in angle epsilon between the two sides. As illustrated in FIG. **14**, the legs **201-204** when the implant **210** is in the insertion position **300** are and have an angle of gamma relative to the bridge **205**, which is approximately 90 degrees. The bridge **205** when the implant **210** is in the insertion position **300** has an angle of theta, which is either 180 degrees or an angle that fits the anatomy of a patient's bones.

It can be seen by FIGS. **13** and **14** that the implant **210** can produce compression in several ways:

- Legs **201** through **204** can be perpendicular to bridge **205** in both the insertion and converging shape, while bridge **205** has angle theta during insertion that moves to smaller angle epsilon causing the four legs to move to a converging position.
- Legs **201** through **204** can have an orthogonal angle gamma during insertion but move to acute angle delta in the converging position.
- A combination of both the bridge bending and the legs moving relative to the bridge.

FIG. **15** shows the implant **210** in bone **20** after implantation. The legs **201-204** are inserted into the bone **195**. The bridge **205** is on the surface of the bone **195**, however, the bridge **205** has a shape that results in less protuberance than prior art implants. The first, second, third, and fourth surfaces **225-228** form the first upper section **230** that is tapered towards the edges. Unlike prior art implant **10**, the implant **210** according to the first embodiment has a more rounded profile when implanted into bone.

FIG. **16** shows an end view the implant **210**. The legs **201-204** all have a uniform width in this view with tapered ends. It is clear that the legs **201-204** could also be tapered or pointed to better insert into bone. The bridge **205** is non-linear and includes a substantially elliptical shape **250** from the end view. However, as will be discussed herein, because the implant **210** is in the converging position **350**, the substantially elliptical shape **250** in this end view results in bridge tapers that are lower profile.

FIGS. **17** and **18** are top and bottom views, respectively, of the implant **10** in the converging position **350**. The bridge **205** as shown in FIG. **17** includes the first, second, third, and fourth surfaces **225-228** that are created due to a method of manufacture, which will be described herein. The first, second, third, and fourth surfaces **225-228** taper towards the edges of the implant **210**. FIG. **18** shows the four legs **201-204** in their converging shape.

FIGS. **19** and **23** are side and perspective views of the implant **210** in he converging position **350**. FIGS. **20-22** are section views of the bridge **205**, taken along lines B-B, C-C, and D-D of FIG. **19**. FIGS. **24-26** are section views of the bridge **205**, taken along lines B-B, C-C, and D-D of FIG. **23**. The section views illustrated in FIGS. **20-22** are taken at the same locations along the bridge **205** as the section views illustrated in FIGS. **24-26**. FIGS. **19-26** illustrate that the cross-section of the bridge **205** changes across the length of the bridge **205**. The cross-hatched areas shown in FIGS. **20-22** and **24-26** illustrated that at all locations of the bridge **205**, the cross section at that location is less than the area and height of the substantially elliptical shape **250** as seen from the end view. Other prior art implants do not have a changing cross section across their connecting bridges. The benefits of the changing cross section is that at all locations of the implant **210**, it can lie at a lower profile to bone with tapered upper surfaces.

FIG. **27** shows a billet **500** of elastic material, such as shape memory nitinol, that is used to create the implant **210**. The billet **500** can be rectangular or square shaped, or any shape that can be conveniently held in machining equipment. The billet **500** has top and bottom surfaces **501** and **504**, end surfaces **502** and **505**, and front and rear surfaces **503** and **506**. In this first embodiment, the billet **500** can be subjected to a variety of manufacturing processes across two surfaces to yield the implant **210**. More particularly, the cutting of the billet **500** using manufacturing processes such as rotating mills, saw blades, electric discharge machining, laser machining, or water jets across two surfaces yields the implant **210**. In this case, the implant **210** is created by EDM from the surface **503**. "Cutting" in the present invention refers to any method of manufacturing that creates a desired shape in a pail and, therefore, is not to be limited to any specific manufacturing method.

The machine traces a path **511** which represents the implant **210** with four barbed legs and the connecting bridge in the converging position **350**, the same as FIG. **12**. It is noted that the portion of path **511** that becomes the bridge **205** has a uniform thickness across the length of the bridge **205**. After the path **511**, the machine traces a path **510** from the surface **502** which is an end view like FIG. **17**. Alternatively, the paths **510** and **511** could be reversed in sequence. The elements of the manufacturing method consist of:

- Cutting the implant **210** in the converging position, which gives the implant designer an option of creating compression in the legs by changing the angle of the bridge, or by changing the angles of the legs relative to the bridge, or both.
- Cutting the implant **210** from two perpendicular surfaces with a single continuous path from each surface and the extension of the two paths until they intersect to form the perimeter and profile of the implant **210**.

Cutting the implant **210** with path **511** that has a uniform width across the entire bridge **205** of implant **210**.

Cutting the implant **210** with the path **510** and the substantially elliptical shape **250** such that the bridge **205** is wider and hence stronger than an implant with uniform width.

Some of the benefits of the manufacturing method shown in FIG. **27** include a resulting implant **210** that has tapered first, second, third, and fourth surfaces **225-228** on the bridge **205**. The bridge **205** is also wider than prior art implants, resulting in more bending strength. The bridge **205** has a non-uniform cross section from end to end, with all points along the bridge lower in profile than the substantially elliptical shape **250**.

The following is an example illustrating the production of an implant **210** from a billet **500** and is presented to aid in the understanding of the manufacturing method shown in FIG. **27**. It should be understood that the steps of operation as well as the location, direction, and order of the cuts and paths may be varied and that the manufacturing method is not limited to the below specific example. Illustratively, the implant **210** may be produced using a single continuous cut of the paths **511** and **510**. Alternatively, the cutting along the paths **511** and **510** may be discrete in that the bridge **205** may be cut completely either before or after each of the legs **201-204** are cut.

A cutting machine begins at point **520** and traces the path **511**. In particular, the machine follows an outer side leg path **522** of a leg path **521** and cuts an outer side portion of the leg **201**. At the end of the outer side leg path **522**, the machine transitions to a second lower section path **524** and follows an outer corner path **525** of the second lower section path **524** to cut an outer portion of the corner **206**. The machine transitions from the outer corner path **525** of the second lower section path **524** to a first upper section path **526** at the first end transition **234** as defined by the plane **232**. Following the first upper section path **526**, the machine cuts the central surface **233**, the first surface **225**, and the second surface **226** of the first upper section **230** that lies between the first end transition **234** and the second end transition **235**. The first upper section path **526** is non-linear in that it follows an arc between the first end transition **234** and the second end transition **235**, although the arc may flatten at the central surface **226** to provide a flattened profile of the bridge **205** at the central surface **226**. The non-linear shape of the first upper section path **526** ensures the removal of material between a plane tangent to the central surface **226** and the first and second surfaces **225** and **226** such the bridge **205** presents a profile lower than bridges with a linear profile. At the second end transition **235** as defined by the plane **232**, the machine transitions to the second lower section path **524** and follows an outer corner path **527** of e second lower section path **524** to cut an outer portion of the corner **209**. The machine transitions from the outer corner path **527** of the second lower section path **524** to a leg path **528** and follows outer side leg path **529** and an inner side leg path **530** to cut outer and inner side portions of the leg **209**. At the end of inner side leg path **530**, the machine transitions to the second lower section path **524** and follows an inner corner path **531** of the second lower section path **524** to cut an inner portion of the corner **209**. Once the end of the inner corner path **531** of the second lower section path **524** is reached, the machine follows a second surface path **532** of the second lower section path **524** to cut the second surface **242**. At the end of the second surface path **532** of the second lower section path **524**, the machine follows a corner path **533** of the second lower section path **524** to cut the corner **216**. The machine transitions from corner path **533** of the second lower section path **524** to a leg path **534** and follows an outer side leg path **535** and an inner side leg path **536** to cut outer and inner side portions of the leg **203**. At the end of inner side leg path **536**, the machine transitions to the second lower section path **524** and follows a corner path **537** of the second lower section path **524** to cut the corner **208**. After reaching the end of the corner path **537** of the second lower section path **524**, the machine follows a central surface path **538** of the second lower section path **524** to cut the central surface **240**. At the end of the central surface path **538** of the second lower section path **524**, the machine follows a corner path **539** of the second lower section path **524** to cut the corner **207**. The machine transitions from corner path **539** of the second lower section path **524** to a leg path **540** and follows an inner side leg path **541** and an outer side leg path **542** to cut outer and inner side portions of the leg **202**. At the end of outer side leg path **542**, the machine transitions to the second lower section path **524** and follows a corner path **555** of the second lower section path **524** to cut the corner **215**. Once the end of the corner path **555** of the second lower section path **524** is readied, the machine follows a first surface path **543** of the second lower section path **524** to cut first surface **241**. After reaching the end of first surface path **543** of the second lower section path **524**, the machine then transitions to an inner corner path **544** of the second lower section path **524** to cut an inner portion of the corner **206**. The machine transitions from the inner corner path **544** of the second lower section path **524** to the leg path **528** and follows an inner side leg path **523** until the point **520** to cut an inner side portion of the leg **201**. Although the legs paths **528** and **540** interrupt the second lower section path **524**, it should be understood that the first surface path **543**, the second surface path **532**, and the central surface path **538** are non-linear in that they are aligned to follow an arc between the first and second leg transitions **243** and **244**, although the arc may increase at the central surface **240** to provide a reduced profile of the bridge **205** at the central surface **240**. The non-linear shape of the second lower section path **524** ensures the removal of material between a plane intersecting the legs **201-204** and the first surface **241**, the second surface **242**, and the central surface **240** such the bridge **205** presents a profile lower than bridges with a linear profile.

The cutting machine begins at point **550** and traces the path **510**. In particular, the machine follows a first face leg path **551** of a leg path **551** and cuts first face portions of the legs **201-204**. At the end of first face leg path **551**, the machine transitions to a second lower section path **552** to cut a portion of the second lower section **231**. The machine transitions from the second lower section path **552** to a first upper section path **553** at the first side transition **236** as defined by the plane **232**. Following the first upper section path **553**, the machine cuts the central surface **233**, the third surface **227**, and the fourth surface **228** of the first upper section **230** that lies between the first side transition **236** and the second end transition **237**. At the second side transition **237** as defined by the plane **232**, the machine transitions to the second lower section path **552** and cuts a portion of the second low section **231**. The machine transitions from the second lower section path **552** to the leg path **551** and follows a first face leg path **554** until the point **550** to cut second face portions of the legs **201-204**. Although the leg path **551** interrupts the second lower section path **552**, it should be understood that the second lower section path **552** and the first upper section path **553** are non-linear in that they define the substantially elliptical shape **250**. As such, the first upper section path **553** is non-linear in that it follows an arc substantially along an ellipse between the first side transition **236** and the second side transition **237**, although the arc may flatten at the central surface **226** to provide a flattened profile of the bridge **205** at the central surface **226**. The non-linear shape of the first upper section path **553** ensures the removal of material between a plane tangent to the central surface **226** and the third and fourth surfaces **225** and **226** such that bridge **205** presents a profile lower than bridges with a linear profile. Furthermore, the second lower section path **552** is non-linear in that it follows an arc substantially along an ellipse between the first side transition **236** and the second side transition **237**. The non-linear shape of the second lower section path **524** ensures the second lower section **231** is wider than the legs **201-204** in order to provide the implant **210** with increased bending strength.

From the foregoing, it should be understood that producing the implant **210** from the billet **500** using a method of manufacture wherein two intersecting non-linear paths are cut from two different directions results in the bridge **205** of implant **210** having a smooth reduced profile composite surface and a non-uniform cross-sectional area. In particular, cutting the non-linear first upper section path **526** and the non-linear second lower section path **524** from a first direction relative to the billet **500** and cutting the non-linear first upper section path **553** and the non-linear second lower section path **552** from a second direction relative to the billet **500** creates the implant **210** having a bridge **205** with tapered first, second, third, and fourth surfaces **225-228**. Moreover, the bridge **205** includes a non-uniform cross-sectional area as illustrated in FIGS. **20-22** and **24-26**. As such, the implant **210** includes a low profile and provides less of protuberance to a patient as well as increased bending strength.

FIG. **28** illustrates an implant **1000** according to a second embodiment. The implant **1000** is shown in a converging position **1150**. The implant **1000** includes legs **1001** and **1002** connected by a bridge **1005**. The implant **1000** is a two-legged version of implant **210** such that the legs **1001** and **1002** are substantially identical to the legs **201** and **204** of the implant **210** and the bridge **1005** is substantially identical to the bridge **205**. The bridge **1005** includes a first upper section **1115**, which is substantially identical to the first upper section **230**, and a second lower section **1116**, which is substantially identical to the second lower section **231**. The first upper section **1115** includes a central surface **1117** and first, second, third, and fourth surfaces **1006-1009**, which are substantially identical the central surface **233** and the first, second, third, and fourth surfaces **225-228**. The second lower section **1116** includes a central surface **1010** and first and second surfaces **1011** and **1012**, which are substantially similar to the central surface **240** and the first and second surfaces **241** and **242**, with the exception that the second lower surface **1116** presents a continuous, uninterrupted surface due to the elimination of interior legs **202** and **203**. Similar to the implant **210**, the implant **1000** has in an insertion position, where the legs **1001** and **1002** are substantially parallel. Substantially the same as the implant **210**, the implant **1000** creates compression from either a bend in the bridge **1005**, the changing the angles of the legs **1001-1002** relative to the bridge **1005**, or a combination of both.

FIG. **29** shows a billet **1050** of elastic material, such as shape memory nitinol, that is used to create the implant **1000**. The billet **1050** can he rectangular or square shaped, or any shape that can be conveniently held in machining equipment. The billet **1050** has top and bottom surfaces **1051** and **1052**, end surfaces **1053** and **1054**, and front and rear surfaces **1055** and **1056**. In this second embodiment, the billet **1050** can be subjected to a variety of manufacturing processes across two surfaces to yield the implant **1000**. More particularly, the cutting of the billet **1050** using manufacturing processes such as rotating mills, saw blades, electric discharge machining, laser machining, or water jets across two surfaces yields the implant **1000**. In this case, the implant **1000** is created by EDM from the surface **1055**. "Cutting" in the present invention refers to any method of manufacturing that creates a desired shape in a part and, therefore, is not to be limited to any specific manufacturing method.

The machine traces a path **1060** which represents the implant **1000** with two barbed legs and the connecting bridge in the converging position, the same as FIG. **29**. It is noted that the portion of path **1060** that becomes the bridge **1005** has a uniform thickness across the length of the bridge **1005**. After the path **1060**, the machine traces a path **1061** from the surface **1053**. The method of manufacturing the implant **1000** is substantially similar to the implant **210**, with the path **1061** being identical to the path **510** and the path **1060** being substantially similar to the path **511** except that the second lower surface **1116** presents a continuous, uninterrupted surface due to the elimination of interior legs **202** and **203**.

FIGS. **30-42** illustrate a third embodiment of an implant **810**. The implant **810** is shown in a converging position **950**. The implant **810** can be made from any elastic material. An example of such a material is a shape memory implant made from nitinol. The implant **810** includes legs **801-804** connected by a bridge **805**. The implant **810** includes corners **806-809** that connect a respective leg **801-804** with the bridge **805**. Each leg **801-804** has a respective tip **811-814**. The legs **801-804** are smooth; however, it is possible to include barbs on legs **801-804** to improve the pull-out resistance of the implant **810**. In the third embodiment, the corners **806-809** store energy when deformed and create a compressive force that moves tips **811-814** angularly between 0 degrees and 90 degrees relative to the central axis **890**. Illustratively, the tips **811-814** may move perpendicular (90 degrees) relative to the central axis **890** such that the linear distance between the tips **811** and **813** and the tips **812** and **814** decreases while the linear distance between the tips **811** and **812** and the tips **813** and **814** remains constant. Conversely, the tips **811-814** may move parallel (0 degrees) relative to the central axis **890** such that the linear distance between the tips **811** and **812** and the tips **813** and **814** decreases while the linear distance between the tips **811** and **813** and the tips **812** and **814** remains constant. Finally, the tips **811-814** may move at an angle between parallel (0 degrees) and perpendicular (90 degrees) relative to the central axis **890** such that the linear distances between each of the tips **811-814** decreases. In the third embodiment, the implant **810** may create compression from a bend in the bridge **805**, the changing the angles of the legs **801-804** relative to the bridge **805**, or a combination of both.

The bridge **805** includes a first upper section **830** and a second lower section **831**. The first upper section **830** is the top portion of the bridge **805** between the corners **806-809**, and the second lower section **831** is the underside portion of the bridge **805** between the corners **806-809**. The first upper section **830** includes a central surface **833** and first, second, third, and fourth surfaces **840-843**. The central surface **833** may be linear to lower the profile of the first upper section **830**. Alternatively, the central surface **833** may be non-linear to provide a smooth transition from the central surface **833** to each of the first, second, third, and fourth surfaces **840-843**.

The first surface **840** is non-linear and tapers from the central surface **833** to a first end transition **871** located at the corner **806** and a second end transition **875** located at the corner **807**. In the third embodiment, the first surface **840** includes a non-linear end portion **915** created at the end of the first surface **840** between the corners **806** and **807** during the manufacture of the implant **810**. The second surface **842** is non-linear and tapers from the central surface **833** to a third end transition **872** located at the corner **808** and a fourth end transition **876** located at the corner **809**. In the third embodiment, the second surface **842** includes a non-linear end portion **916** created at the end of the second surface **842** between the corners **806** and **807** during the manufacture of the implant **810**. The first, second, third, and fourth end transitions **871**, **872**, **875**, and **876** are between the first upper section **830** and the second lower section **831**. The third surface **841** is non-linear and tapers from the central surface **833** to a first side transition **836** between the first upper section **830** and the second lower section **831**. In the third embodiment, the third surface **841** includes a non-linear side portion **917** created in a central portion of the third surface **841** at the first side transition **836** during the manufacture of the implant **810**. The fourth surface **843** is non-linear and tapers from the central surface **833** to a second side transition **837** between the first upper section **830** and the second lower section **831**. In the third embodiment, the fourth surface **843** includes a non-linear side portion **918** created in a central portion of the fourth surface **843** at the second side transition **837** during the manufacture of the implant **810**. The first, second, third, and fourth surfaces **841-843** in the third embodiment each taper from the central surface **833** at an angle of between 5 degrees and 85 degrees when measured from a plane tangent to the central surface **833**. The tapering of the first, second, third, and fourth surfaces **841-843** from the central surface **833** provides the implant **810** with a first upper section **830** that has a smooth composite surface and a non-uniform cross-sectional thickness between the first, second, third, and fourth end transitions **871-874** as illustrated in FIGS. **34-36** and **38-40**. As a result, the implant **810** includes a low profile and provides less of protuberance to a patient.

The second lower section **831** includes a central surface **880**, a first surface **881**, a second surface **882**, a third surface **883**, and a fourth surface **884**. The central surface **880** is non-linear to provide a smooth transition from the central surface **880** to each of the first, second, third, and fourth surfaces **881-884**. As described more fully herein with reference to FIGS. **32** and **42**, the non-linear end portions **915** and **916** and the non-linear side portions **917** and **918** are created during manufacture of the central surface **880**. The first surface **881** is non-linear and tapers from the central surface **880** to a first leg transition **837** located at the corner **806** and a second leg transition **894** located at the corner **807**. The second surface **882** is non-linear and tapers from the central surface **833** to a third leg transition **895** located at the corner **808** and a fourth leg transition **896** located at the corner **809**. The first, second, third, and fourth leg transitions **893**, **894**, **895**, and **896** are between the first upper section **830** and the second lower section **831**. The third surface **883** is non-linear and tapers from the central surface **880** to a first side transition **888** between the first upper section **830** and the second lower section **831**. The fourth surface **884** is non-linear and tapers from the central surface **880** to a second side transition **889** between the first upper section **830** and the second lower section **831**.

In the third embodiment, the first, second, third, and fourth surfaces **881-884** each taper from the central surface **880** at an angle of between 5 degrees and 85 degrees when measured from a plane tangent to the central surface **880**. The tapering of the first, second, third, and fourth surfaces **881-884** from the central surface **880** provides the implant **810** with a second lower section **831** that has a smooth composite surface and a non-uniform cross-sectional thickness between the first, second, third, and fourth leg transitions **893-896** as illustrated in FIGS. **34-36** and **38-40**. As a result, the implant **810** includes a low profile and provides less of protuberance to a patient.

FIG. **31** illustrates the implant **810** in the converging position **950** and with barbs on legs **801-804**. In the converging position **950**, each of the legs **801-804** has an acute angle of less than 90 degrees relative to the bridge **805**. The implant **810** also has an insertion position that allows the implant **810** to be inserted into bone. In the insertion position, each of the legs **801-804** are substantially parallel such that the legs **801-804** have an angle of approximately 90 degrees relative to the bridge **805**. The bridge **805** has a bend in the middle that results in angle of less than 180 degrees between the two sides. The bridge **205** when the implant **210** is in the insertion position **300** has an angle, which is either 180 degrees or an angle that fits the anatomy of a patient's bones.

In the converging position **950**, the bridge **805** has been manufactured such that there are tapers on bridge **805** towards the edges of the bridge, labeled as first, second, third, and fourth surfaces **840-843**. The first, second, third, and fourth surfaces **840-843** result in less protuberance than the prior art implants when implanted in bone, because rather than being orthogonal to each other they are directed at angles that result in a more rounded bridge. In addition, the bridge **805** is wider than the legs **801-804**, such that the implant **810** would be stronger in bending for the same dimension legs than prior art implant **10**.

FIG. **32** is a bottom view of the implant **810** in the converging position **950**. The bridge **805** includes the central surface **880** and the first, second, third, and fourth surfaces **881-884** that are created due to a method of manufacture, which will be described herein. The first, second, third, and fourth surfaces **881-884** taper towards the edges of the implant **810**.

FIGS. **33** and **37** are side and perspective views of the implant **810** in the converging position **950**. FIGS. **34-36** are section views of the bridge **805**, taken along lines E-E, F-F, and G-G of FIG. **33**. FIGS. **38-40** are section views of the bridge **805**, taken along lines E-E, F-F, and G-G of FIG. **37**. The section views illustrated in FIGS. **34-36** are taken at the same locations along the bridge **805** as the section views illustrated in FIGS. **38-40**. FIGS. **33-40** illustrate that the cross-section of the bridge **805** changes across the length of the bridge **805**. The cross-hatched areas shown in FIGS. **34-36** and **38-40** illustrate that at all locations of the bridge **805**, the cross section at that location is less than the area and height of the bridge **805** when viewed at an end. Other prior art implants do not have a changing cross-section across their connecting bridges. The benefits of the changing cross-section is that at all locations of the implant **810**, it can lie at a lower profile to bone with tapered upper surfaces.

FIG. **41** shows a billet **1500** of elastic material, such as shape memory nitinol, that is used to create the implant **810**. The billet **1500** can be rectangular or square shaped, or any shape that can be conveniently held in machining equipment. The billet **1500** has top and bottom surfaces **1503** and **1506**, end surfaces **1502** and **1505**, and front and rear surfaces **1501** and **1504**. In this third embodiment, the billet **1500** can be subjected to a variety of manufacturing processes across two surfaces to yield the implant **810**. More particularly, the cutting of the billet **1500** using manufacturing processes such as rotating mills, saw blades, electric discharge machining, laser machining, or water jets across two surfaces yields the implant **810**. In this case, the implant **810** is created by EDM from the surface **1501**. "Cutting" in the present invention refers to method of manufacturing that creates a desired shape in a part and, therefore, is not to be limited to any specific manufacturing method.

The machine traces a path **1510** from the surface **1501**, which rrepresents the implant **810** in the converging position **950**. After the path **1510**, the machine traces a path **1511** from the surface **1502**. Alternatively, the paths **1510** and **1511** could be reversed in sequence. The elements of the manufacturing method consist of:

- Cutting the implant **810** in the converging position, which gives the implant designer an option of creating compression in the legs by changing the angle of the bridge, or by changing the angles of the legs relative to the bridge, or both.
- Cutting the implant **810** from two perpendicular surfaces with a single continuous path from each surface.
- Cutting the implant **810** with path **1510**, wherein the path **1510** has a uniform separation around the path.
- Cutting the implant **810** with the path **1511** such that the bridge **805** of resultant implant **810** is wider and hence stronger than an implant with width equal to the width of the legs.

Some of the benefits of the manufacturing method shown in FIG. **41** include a resulting implant **810** that has tapered first, second, third, and fourth surfaces **840-843** on the bridge **805**. The bridge **805** is also wider than prior art implants, resulting in more bending strength. The bridge **805** has anon-uniform cross section from end to end, with all points along the bridge lower in profile than either paths **1510** and **1511**.

The following is an example illustrating the production of an implant **810** from a billet **1500** and is presented to aid in the understanding of the manufacturing method shown in FIGS. **41** and **42**. It should be understood that the steps of operation as well as the location, direction, and order of the cuts and paths may be varied and that the manufacturing method is not limited to the below specific example. Illustratively, the implant **810** may be produced using a single continuous cut of the paths **1510** and **1511**. Alternatively, the cutting along the paths **1510** and **1511** may be discrete in that the bridge **805** may be cut completely either before or after each of the legs **801-804** are cut.

A cutting machine begins at point **1520** and traces the path **1510**. In particular, the machine follows an outer side leg path **1522** of a leg path **1521** and cuts an outer side portion of the legs **801** and **802**. At the end of the outer side leg path **1522**, the machine transitions to a first corner set path **1524** and follows an outer corner path **1525** to cut an outer end portion of the corners **806** and **807**. The machine transitions from the outer corner path **1525** to an end upper section path **1526** at the first end transitions **871** and **875**. In the third embodiment, the end upper section path **1526** includes a first surface path **1527**, a central surface path **1528**, and a second surface path **1529**. Following each of the first surface path **1527**, the central surface path **1528**, and the second surface path **1529** of the end upper section path **1526**, the machine cuts the first surface **840**, a portion of the central surface **833**, and the second surface **842** of the first upper section **830** that lies between the end transitions **871** and **875** and the end transitions **872** and **876**. The end upper section path **1526** is non-linear in that it follows an arc between the end transitions **871** and **875** and the end transitions **872** and **876**. In particular, the first surface path **1527**, the central surface path **1528**, and the second surface path **1529** have a substantially similar arc radius in that the first surface path **1527**, the central surface path **1528**, and the second surface path **1529** follow a substantially uniform arc along the entire length of the end upper section path **1526**, although the arc may flatten at the central surface **833** to provide a flattened profile of the bridge **805** at the central surface **833**. The non-linear shape of the end upper section path **1526** ensures the removal of material between a plane tangent to the central surface **833** and the first and second surfaces **840** and **842** such the bridge **805** presents a profile lower than bridges with a linear profile. At the end transitions **872** and **876**, the machine transitions to a second corner set path **1530** and follows an outer corner path **1531** to cut an outer end portion of the corners **808** and **809**. The machine transitions from the outer corner path **1531** to a leg path **1532** and follows an outer side leg path **1533** and an inner side leg path **1534** to cut outer and inner side portions of the legs **803** and **804**. At the end of inner side leg path **1534**, the machine transitions to the second corner set path **1530** and follows an inner corner path **1535** to cut an inner end portion of the corners **808** and **809**. The machine transitions from the inner corner path **1535** to an end lower section path **1536** at the third and fourth leg transitions **895** and **896**. In the third embodiment, the end lower section path **1536** includes a first surface path **1539**, a central surface path **1538**, and a second surface path **1537**. Following, the second surface path **1537**, the central surface path **1538**, and the first surface path **1539** of the end lower section path **1536**, the machine cuts the second surface **881**, a portion of the central surface **880**, and the first surface **882** of the second lower section **831** that lies between the third and fourth leg transitions **895** and **896** and the first and second leg transitions **893** and **894**. The end lower section path **1536** is non-linear in that it follows an arc between the third and fourth leg transitions **895** and **896** and the first and second leg transitions **893** and **894**. In a first path configuration, the first surface path **1539**, the central surface path **1538**, and the second surface path **1537** have a substantially similar arc radius in that the first surface path **1539**, the central surface path **1538**, and the second surface path **1537** follow a substantially uniform arc along the entire length of the end lower section path **1536**, although the arc may flatten at the central surface **880** to provide a flattened profile of the bridge **805** at the central surface **880**. In an alternative path configuration according to the third embodiment, the first surface path **1539** and the second surface path **1537** have a substantially similar arc radius and follow a substantially symmetrical and uniform arc. The central surface path **1538**, however, has an arc radius that is smaller than the arc radii of the first and second surface paths **1539** and **1537**. As a result, the central surface path **1538** deviates from the first and second surface paths **1539** and **1537** in a direction towards the end upper section path **1526**, thereby reducing the cross-section of the bridge **805** at the central surfaces **833** and **880**. Moreover, in deviating towards the end upper section path **1526**, the central surface path **1538** removes material from the bridge **805** to create the non-linear side portion **917** in the third surface **841** at the first side transition **836** and the non-linear side portion **918** in the fourth surface **842** at the first side transition **837**. The non-linear shape of the end lower section path **1536** ensures the removal of material between a plane tangent to the central surface **880** and the first and second surfaces **881** and **882** such the bridge **805** presents a profile lower than bridges with a linear profile. At the first and second leg transitions **893** and **894**, the machine transitions to the first corner set path **1524** and follows an inner corner path **1540** to cut an inner end portion of the corners **806** and **807**. The machine transitions from the inner corner path **1540** to the leg path **1521** and follows an inner side leg path **1541** until the point **1520** to cut inner side portions of the legs **801** and **802**.

The cutting machine begins at point **1620** and traces the path **1511**. In particular, the machine follows an outer side leg path **1622** of a leg path **1621** and cuts an outer face portion of the legs **801** and **803**. At the end of the outer side leg path **1622**, the machine transitions to a first corner set path **1624** and follows an outer corner path **1625** to cut an outer side portion of the corners **806** and **808**. The machine transitions from the outer corner path **1625** to a side upper section path **1626** at the first side transition **836**. In the third embodiment, the side upper section path **1626** includes a third surface path **1627**, a central surface path **1628**, and a fourth surface path **1629**. Following each of the third surface path **1627**, the central surface path **1628**, and the fourth surface path **1629** of the side upper section path **1626**, the machine cuts the third surface **841**, a portion of the central surface **833**, and the fourth surface **843** of the first upper section **830** that lies between the side transitions **836** and **837**. The side upper section path **1626** is non-linear in that it follows an arc between the side transitions **836** and **837**. In particular, the third surface path **1627**, the central surface path **1628**, and the fourth surface path **1629** have a substantially similar arc radius in that the third surface path **1627**, the central surface path **1628**, and the fourth surface path **1629** follow a substantially uniform arc along the entire length of the side upper section path **1626**, although the arc may flatten at the central surface **833** to provide a flattened profile of the bridge **805** at the central surface **833**. The non-linear shape of the side upper section path **1626** ensures the removal of material between a plane tangent to the central surface **833** and the third and fourth surfaces **841** and **843** such the bridge **805** presents a profile lower than bridges with a linear profile. At the side transition **837**, the machine transitions to a second corner set path **1630** and follows an outer corner path **1631** to cut an outer side portion of the corners **807** and **809**. The machine transitions from the outer corner path **1631** to a leg path **1632** and follows an outer side leg path **1633** and an inner side leg path **1634** to cut outer and inner side portions of the legs **802** and **804**. At the end of inner side leg path **1634**, the machine transitions to the second corner set path **1630** and follows an inner corner path **1635** to cut an inner face portion of the corners **807** and **809**. The machine transitions from the inner corner path **1635** to a side lower section path **1636** at the second side transition **889**. In the third embodiment, the side lower section path **1636** includes a third surface path **1639**, a central surface path **1638**, and a fourth surface path **1637**. Following the fourth surface path **1637**, the central surface path **1638**, and the third surface path **1639** of the side lower section path **1636**, the machine cuts the fourth surface **884**, a portion of the central surface **880**, and the third surface **883** of the second lower section **831** that lies between the first and second side transitions **888** and **889**. The side lower section path **1636** is non-linear in that it follows an arc between the first and second side transitions **888** and **889**. In a first path configuration, the third surface path **1639**, the central surface path **1638**, and the fourth surface path **1637** have a substantially similar arc radius in that the third surface path **1639**, the central surface path **1638**, and the fourth surface path **1637** follow a substantially uniform arc along the entire length of the side lower section path **1636**, although the arc may flatten at the central surface **880** to provide a flattened profile of the bridge **805** at the central surface **880**. In an alternative path configuration according to the third embodiment, the third surface path **1639** and the fourth surface path **1637** have a substantially similar arc radius and follow a substantially symmetrical and uniform arc. The central surface path **1638**, however, has an arc radius that is smaller than the arc radii of the third and fourth surface paths **1639** and **1637**. As a result, the central surface path **1638** deviates from the third and fourth surface paths **1639** and **1637** in a direction towards the side upper section path **1626**, thereby reducing the cross-section of the bridge **805** at the central surfaces **833** and **880**. Moreover, in deviating towards the side upper section path **1626**, the central surface path **1638** removes material from the bridge **805** to create the non-linear end portion **915** in the first surface **840** between the end transitions **871** and **875** and the non linear end portion **916** in the second surface **842** between the end transitions **872** and **876**. The non-linear shape of the end lower section path **1636** ensures the removal of material between a plane tangent to the central surface **880** and the third and fourth surfaces **883** and **884** such the bridge **805** presents a profile lower than bridges with a linear profile. At the first side transition **888**, the machine transitions to the first corner set path **1624** and follows an inner corner path **1640** to cut an inner side portion of the corners **806** and **808**. The machine transitions from the inner corner path **1640** to the leg path **1621** and follows an inner side leg path **1641** until the point **1620** to cut inner side portions of the legs **801** and **803**.

From the foregoing, it should be understood that producing the implant **810** from the billet **1500** using a method of manufacture wherein two intersecting non-linear paths are cut from two different directions results in the bridge **805** of implant **810** having a smooth reduced profile composite surface and a non-uniform cross-sectional area. In particular, cutting the non-linear end upper section path **1526** and the non-linear end lower section path **1536** from a first direction relative to the billet **1500** and cutting the non-linear side upper section path **1626** and the non-linear side lower section path **1636** from a second direction relative to the billet **1500** creates the implant **810** having a bridge **805** with tapered first, second, third, and fourth surfaces **840-843** and **881-884**. Moreover,the bridge **805** includes a non-uniform cross-sectional area as illustrated in FIGS. **34-36** and **38-40** such that the implant **810** includes a low profile and provides less of protuberance to a patient as well as increased bending strength.

It is clear that the advanced implant designs of implants **210**, **810**, and **1000** offer advantages over prior art implants. The advantages include:

- Compression resulting from either the motion of the legs relative to the bridge, or the motion of the bridge alone, or a combination of both.
- A lower profile bridge with less protuberance for a surgery patient by having tapered and beveled surfaces on the upper surface of the bridge.
- Bridge surfaces that are not orthogonal to each other, such that all surfaces exposed above the bone and under the skin of the patient are non-orthogonal.
- A bridge that changes cross section between the two legs such that at any point the height of the bridge is shorter and wider than the width of the legs.
- A method of manufacturing the advanced design implants that uses two orthogonal paths to create the implant in its converging shape.

A method of manufacturing that causes two paths to intersect such that the intersection becomes the perimeter and profile of a shape memory implant in its converging position.

Although the present invention has been described in terms of the foregoing preferred embodiments, such description has been for exemplary purposes only and, as will be apparent to those of ordinary skill in the art, many alternatives, equivalents, and variations of varying degrees will fall within the scope of the present invention. That scope, accordingly, is not to be limited in any respect by the foregoing detailed description; rather, it is defined only by the claims.

The invention claimed is:

1. An orthopedic implant, comprising:

a bridge including first and second ends and first and second sides;

a first leg extending from the first end of the bridge;

a second leg extending from the second end of the bridge;

the bridge, comprising a first section and a second section, wherein the first section comprises:

a central surface,

a first surface that tapers from the central surface to a first end transition at the first end of the bridge,

a second surface that tapers from the central surface to a second end transition at the second end of the bridge, and

the tapers of the first and second surfaces provide the first section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant; and

the orthopedic implant comprising a shape memory material such that the orthopedic implant is movable between an insertion shape and an implanted shape.

2. The orthopedic implant according to claim **1**, wherein the first section further comprises:

a third surface that tapers from the central surface to a first side transition at the first side of the bridge;

a fourth surface that tapers from the central surface to a second side transition at the second side of the bridge; and

the tapers of the third and fourth surfaces provide the first section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant.

3. The orthopedic implant according to claim **2**, wherein each of the first, second, third, and fourth surfaces taper from the central surface following a non-linear profile.

4. The orthopedic implant according to claim **2**, wherein the first, second, third, and fourth surfaces are non-orthogonal, thereby providing the bridge with a non-uniform cross-section that flattens the profile of the orthopedic implant.

5. The orthopedic implant according to claim **1**, wherein:

the first section is an upper section and the second section is a lower section; and

the second section, comprises:

a central surface,

a first surface that tapers from the central surface to the first leg at the first end of the bridge,

a second surface that tapers from the central surface to a second leg at the second end of the bridge, and

the tapers of the first and second surfaces provide the second section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant.

6. The orthopedic implant according to claim **5**, wherein each of the first and second surfaces of the second section taper from the central surface of the second section following a non-linear profile.

7. The orthopedic implant according to claim **1**, wherein the first and second legs move during movement of the orthopedic implant between its insertion shape and its implanted shape.

8. The orthopedic implant according to claim **1**, wherein the bridge moves during movement of the orthopedic implant between its insertion shape and its implanted shape.

9. The orthopedic implant according to claim **1**, wherein the first and second legs and the bridge move during movement of the orthopedic implant between its insertion shape and its implanted shape.

10. The orthopedic implant according to claim **1**, further comprising third and fourth legs extending from the second section.

11. An orthopedic implant, comprising:

a bridge including first, second, third, and fourth corners;

a first leg extending from the first corner of the bridge;

a second leg extending from the second corner of the bridge;

a third leg extending from the third corner of the bridge;

a fourth leg extending from the fourth corner of the bridge;

the bridge, comprising a first section and a second section, wherein the first section comprises:

a central surface,

a first surface that tapers from the central surface to a first end transition at the first corner of the bridge and a second end transition at the second corner of the bridge,

a second surface that tapers from the central surface to a third end transition at the third corner of the bridge and a fourth end transition at the fourth corner of the bridge, and

the tapers of the first and second surfaces provide the first section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant; and

the orthopedic implant comprising a shape memory material such that the orthopedic implant is movable between an insertion shape and an implanted shape.

12. The orthopedic implant according to claim **11**, wherein the first section further comprises:

a third surface that tapers from the central surface to a first side transition at the first section;

a fourth surface that tapers from the central surface to a second side transition at the first section; and

the tapers of the third and fourth surfaces provide the first section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant.

13. The orthopedic implant according to claim **12**, wherein each of the first, second, third, and fourth surfaces taper from the central surface following a non-linear profile.

14. The orthopedic implant according to claim **12**, wherein the first, second, third, and fourth surfaces are non-orthogonal, thereby providing the bridge with a non-uniform cross-section that flattens the profile of the orthopedic implant.

15. The orthopedic implant according to claim **11**, wherein the first surface includes a non-linear end portion between the first and second corners of the bridge.

16. The orthopedic implant according to claim **11**, wherein the second surface includes a non-linear end portion between the third and fourth corners of the bridge.

17. The orthopedic implant according to claim 12, wherein the third surface includes a non-linear end portion at the first side transition.

18. The orthopedic implant according to claim 12, wherein the fourth surface includes a non-linear end portion at the second side transition.

19. The orthopedic implant according to claim 11, wherein:

the first section is an upper section and the second section is a lower section; and

the second section, comprises:

a central surface,

a first surface that tapers from the central surface to a first leg transition at the first corner of the bridge and a second leg transition at the second corner of the bridge,

a second surface that tapers from the central surface to a third leg transition at the third corner of the bridge and a fourth leg transition at the fourth corner of the bridge, and

the tapers of the first and second surfaces provide the second section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant.

20. The orthopedic implant according to claim 19, wherein the second section further comprises:

a third surface that tapers from the central surface to a first side transition at the second section;

a fourth surface that tapers from the central surface to a second side transition at the second section; and

the tapers of the third and fourth surfaces provide the second section with a non-uniform cross-section, thereby flattening the profile of the orthopedic implant.

21. The orthopedic implant according to claim 20, wherein each of the first, second, third, and fourth surfaces of the second section taper from the central surface of the second section following a non-linear profile.

22. The orthopedic implant according to claim 19, wherein the first surface includes a non-linear end portion between the first and second corners of the bridge.

23. The orthopedic implant according to claim 19, wherein the second surface includes a non-linear end portion between the third and fourth corners of the bridge.

24. The orthopedic implant according to claim 20, wherein the third surface includes a non-linear end portion at the first side transition.

25. The orthopedic implant according to claim 20, wherein the fourth surface includes a non-linear end portion at the second side transition.

26. The orthopedic implant according to claim 11, wherein the first, second, third, and fourth legs move during movement of the orthopedic implant between its insertion shape and its implanted shape.

27. The orthopedic implant according to claim 11, wherein the bridge moves during movement of the orthopedic implant between its insertion shape and its implanted shape.

28. The orthopedic implant according to claim 11, wherein the first, second, third, and fourth legs and the bridge move during movement of the orthopedic implant between its insertion shape and its implanted shape.

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